ENERGY, MINES AND
RESOURCES CANADA

SCIENCE AND TECHNOLOGY

FINAL REPORT

A STUDY OF THE OPTIMUM CONTROL AND CONSERVATION OF ENERGY IN THE CRYSTALLIZATION, DRYING AND COOLING OF POTASH

MAY, 1983

KILBORN
(SASKATCHEWAN) LTD.

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May 3, 1983

DEPARTMENT OF ENERGY, MINES AND RESOURCES
CANMET, Mineral Sciences Laboratories
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ATTENTION: MR. G. W. RILEY

Dear Mr. Riley:

I am pleased to submit herewith 25 copies of the final Kilborn report entitled:

"A Study of the Optimum Control and Energy Conservation in the Crystallization, Drying and Cooling of Potash"

in compliance with the D.S.S. Contract Number OSQ82-00204 and CANMET Project Number 410104.

Enclosed also is the listing of the computer program known as COMEBAL which was developed during the course of the work.

It has been a most interesting study and I wish to express Kilborn's appreciation for your advice and support. Should there be any questions regarding the study we would be most willing to reply.

Yours very truly,

D. N. Madge, P. Eng.
Manager Process Control Systems

DNM/psk

Enclosure

cc Mrs. M. Brock - Depart. of Supply & Services

COPY

A STUDY OF THE OPTIMUM CONTROL AND CONSERVATION OF ENERGY IN THE CRYSTALLIZATION, DRYING AND COOLING OF POTASH

FINAL REPORT

BY

KILBORN (SASKATCHEWAN) LTD.

WORK ON THE PROJECT WAS CONDUCTED UNDER THE AUSPICES OF THE CANADA CENTRE FOR MINERAL AND ENERGY TECHNOLOGY, ENERGY MINES AND RESOURCES CANADA

MICROMEDIA

DSS FILE NUMBER : 17SQ.23440-2-9172
DSS CONTRACT SERIAL NUMBER : OSQ82-00204
CANMET PROJECT NUMBER : 410104
CANMET SCIENFIFIC AUTHORITY : MR. G. W. RILEY

139 pp

COPY 32

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1.0 THE OPTIMUM CONTROL OF THE CRYSTALLIZATION DRYING AND COOLING OF POTASH

1.1 INTRODUCTION

Crystallization and product drying are the most energy intensive processes in the beneficiation of potash ores. Crystallizers are cyclical in nature and the major unit operations that form this circuit have long retention times. These circuits operate with variable feed rate and throughout there are important process variables that are not directly measurable.

Crystallization circuits are complex yet they have great potential for productivity improvement. Moreover, crystallization as a process is becoming increasingly important in the refining of a wide class of industrial minerals and chemicals.

This report deals with a methodology for the analysis of the KCl-NaCl-H_2O system in the presence of minor amounts of other soluble and insoluble materials. The methodology is illustrated through the case of a dissolving/ recrystallization circuit for the production of white muriate of potash which is nearly pure crystalline KCl. The example circuit consists of crystallizer units which operate by the natural nucleation and growth of KCl crystals in a supersaturated crystal suspension. The existing circuit at Central Canada Potash has been sampled through a designed experiment in order to provide a data base for the development and refinement of a control methodology.

In addition, the report deals with the general problem of optimal crystallizer control and examines control from the following points of view:

- they do not provide a proper treatment of the KCl-NaCl-H_2O phase chemistry,

- the statistical treatment of measured variables does not gauge the correct relative importance of individual measurements,

- the methods require unwarranted assumptions about certain unmeasurable variables,

- some of the existing computer based systems are proprietary to process manufacturers and

- those that are available consist of poor quality software or software that is poorly documented

In August 1982 a general methodology for the balancing of mass and enthalpy in potash circuits was developed by Kilborn. This consisted of a mathematical formulation of mass/energy relations and an objective function for optimization. This optimization would yield a consistent (coherent) balance for a potash circuit which would approximate the nearest equilibrium for the process at the time of measurement.

The question remained as to the practical value of this development. Moreover, at issue was the further funding of this development should the route prove to be of value.

Application for a grant to pursue these questions was made to the Department of Supply and Services Canada under the Unsolicited Proposals program. Sponsorship for the work was obtained from the Mineral Sciences Laboratory of the Canada Center for Mineral and Energy Technology CANMET.

In December 1982 a contract was awarded to Kilborn by D.S.S. and work began in January 1983 with the following objectives:

- Survey the problems of crystallizer control throughout the Saskatchewan Potash Industry in order to determine the development objectives of the industry.

- If warranted, develop the Kilborn control methodology with the goal of assisting the improvement of crystallizer control in the industry.

- Select an appropriate circuit for demonstration of the technology.

- Attempt to improve the operation of this circuit.

- Develop a general control strategy in conceptual/analytical form.

- Outline a program for further work.

- Drying and cooling process considerations were to be viewed through later developments and crystallizer model generalization.

2.2 INITIAL SURVEY

All Companies in the Saskatchewan Potash Industry were approached initially by letter, to see if they would be interested in participating in the study.

From the list, so canvassed, three replied with interest. Others declined for reasons of a proprietary nature and others declined due to projected shutdowns during the study period.

The three interested replies were from:

- Central Canada Potash (one crystallization circuit)
- Cominco Potash (one crystallization circuit) and
- International Minerals and Chemicals (two plants and three crystallization circuits)

These companies were visited at their plants and the study plan was reviewed and further developed. All plants were toured. Particular attention was given to the review of their development plans.

2.3 OBJECTIVES OF CONTROL AND OPERATION

High on the list of concern for all companies participating in the study is the energy cost of crystallizer product per tonne produced. Synonymous with this is the control of saturation throughout the crystallizer circuit.

2.3.1 Product Quality

Control of product size and purity of the product rank next in importance.

2.3.2 Process Identification

Overall, there is a great concern over the difficulty in determining where the process lies in terms of what Control Engineers call the "position in state space".

Not knowing where the process lies can be shown to be the central issue governing the improvement of process operation. If the process could be identified as being in such and such a state and trending in such and such a direction it would be possible to seek improvements provided it were known where the nearest equilibrium lies.

2.3.3 Measurement

Each of the three plants illustrate innovations in process control. At CCP use is being made of on-stream analysis for the measurement of KCl via emissions of gamma rays from the naturally occurring K^{40} isotope of potassium. Cominco are advanced in the use of process computers for the regulation of their circuits and the IMC K-2 plant incorporates an additional crystallizer circuit (Hi KCl) for production of industrial grade product.

In many ways all of the operating Companies feel that their ability to measure key variables leaves much to be desired from the standpoint of accuracy and completeness. Moreover, there is no accord on the make-up of the appropriate set of key variables or the requisite degree of measurement accuracy for each measurement. Completeness implies that the measurement set consists of a set of measurements which will define where the process lies and will represent the process of change sufficiently well to enable improvement.

A complete list of variables also implies a control objective that, if pursued, will secure economical operation. Clearly, progress in determing the "state of the process" and measurement go hand-in-hand. Also the study has revealed that a means of determining "A Coherent Mass Enthalpy Balance" is vital to meeting any or all of the aforementioned control objectives.

2.4 EXPERIMENTAL DESIGN AND SAMPLING

The presence of high levels of magnesium and an otherwise greater degree of circuit complexity mitigated against the intensive study of the IMC circuit during the current phase of the study. Nevertheless, the possibility of greater long range benefits will prompt later consideration of this plant.

Due to the timing of the study, Central Canada Potash were in the best position to provide manpower for the sampling of their circuit in early March. Also their circuit complexity was the least which would make for easier diagnosis of computer programming problems.

The Central Canada Potash circuit was sampled according to a Kilborn experimental design over a four hour period in early March. The results of the analysis are reviewed later in the report.

3.0 PROCESS TECHNOLOGY DESCRIPTION

3.1 INTRODUCTION

Figure I shows a schematic diagram of a potash crystallizer of the kind and class at Central Canada Potash. It is very similar to the one at Cominco but considerably different from those at IMC. However, they are all fundamentally the same from the point of view of the following mathematical analysis. In order to fully illustrate what follows a simplified description of the Central Canada Potash circuit will be given.

3.2 THE CENTRAL CANADA POTASH CRYSTALLIZER CIRCUIT

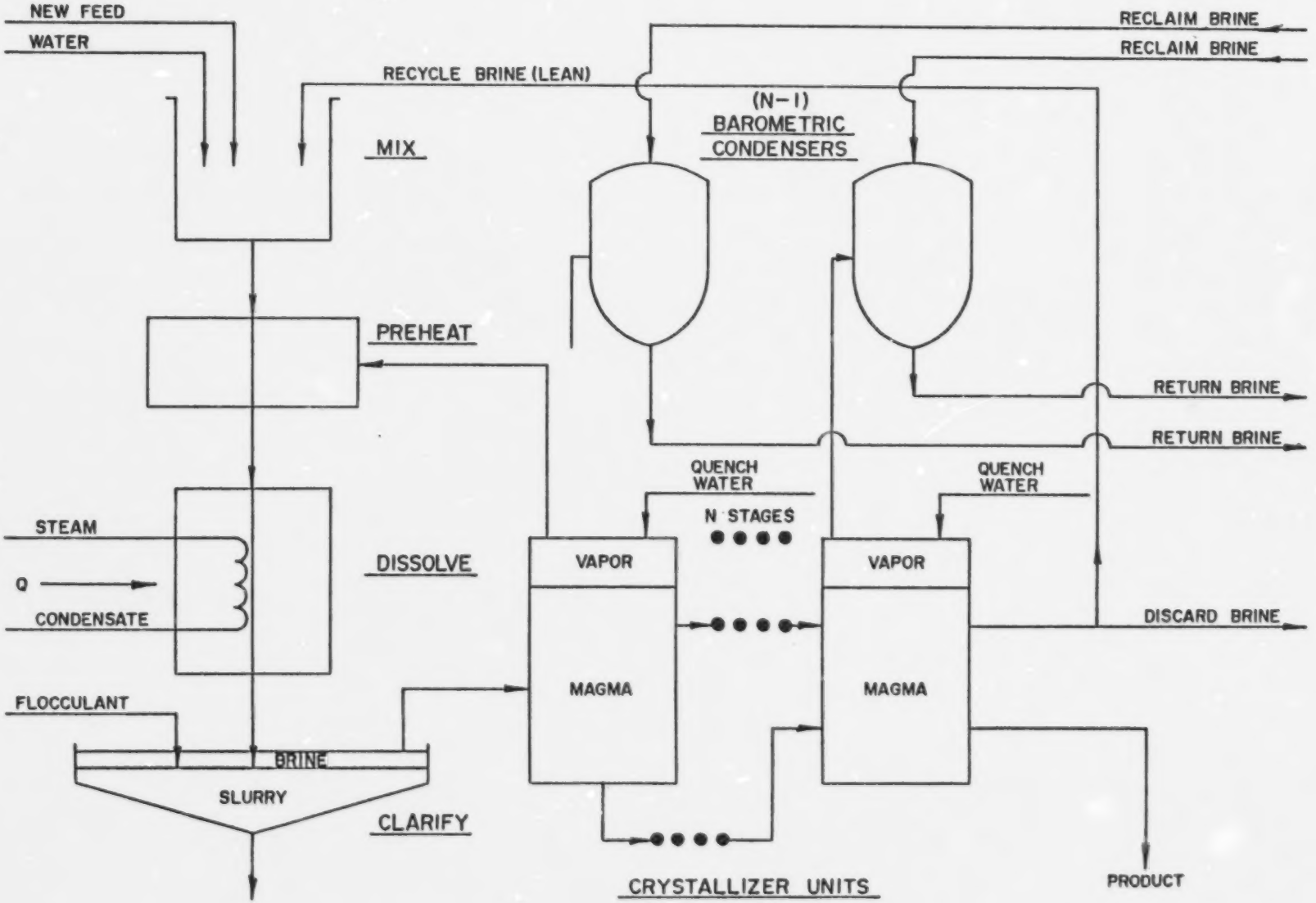
In the following, the topological concept of node in a network and the process concept of unit operation will be used interchangeably. This will make the somewhat complicated mathematics easier to understand later on. Reference should be made to Figures I and II.

3.2.1 Node 1 - Dust Mix Tank

New material is fed to this process unit from various places in the potash plant such as effluent flotation and points of dust collection. It is high KCl material that deviates from final product specification due to size analysis or composition. It is the function of the crystallizer to recover the KCl values in the form of product.

The dust mix tank is also the point for collection of lean brine that has been recycled from the last (fourth) stage of crystallization.

Water is added to the dust mix tank at Central Canada Potash in order to avoid NaCl precipitation in the dissolver heat exchanger (see Node 3). This is a recent innovation and has a bearing on the achievement optimally efficient operation.



BLOCK PROCESS DIAGRAM OF A POTASH CRYSTALLIZER

FIGURE I

CENTRAL CANADA POTASH CIRCUIT TOPOLOGY

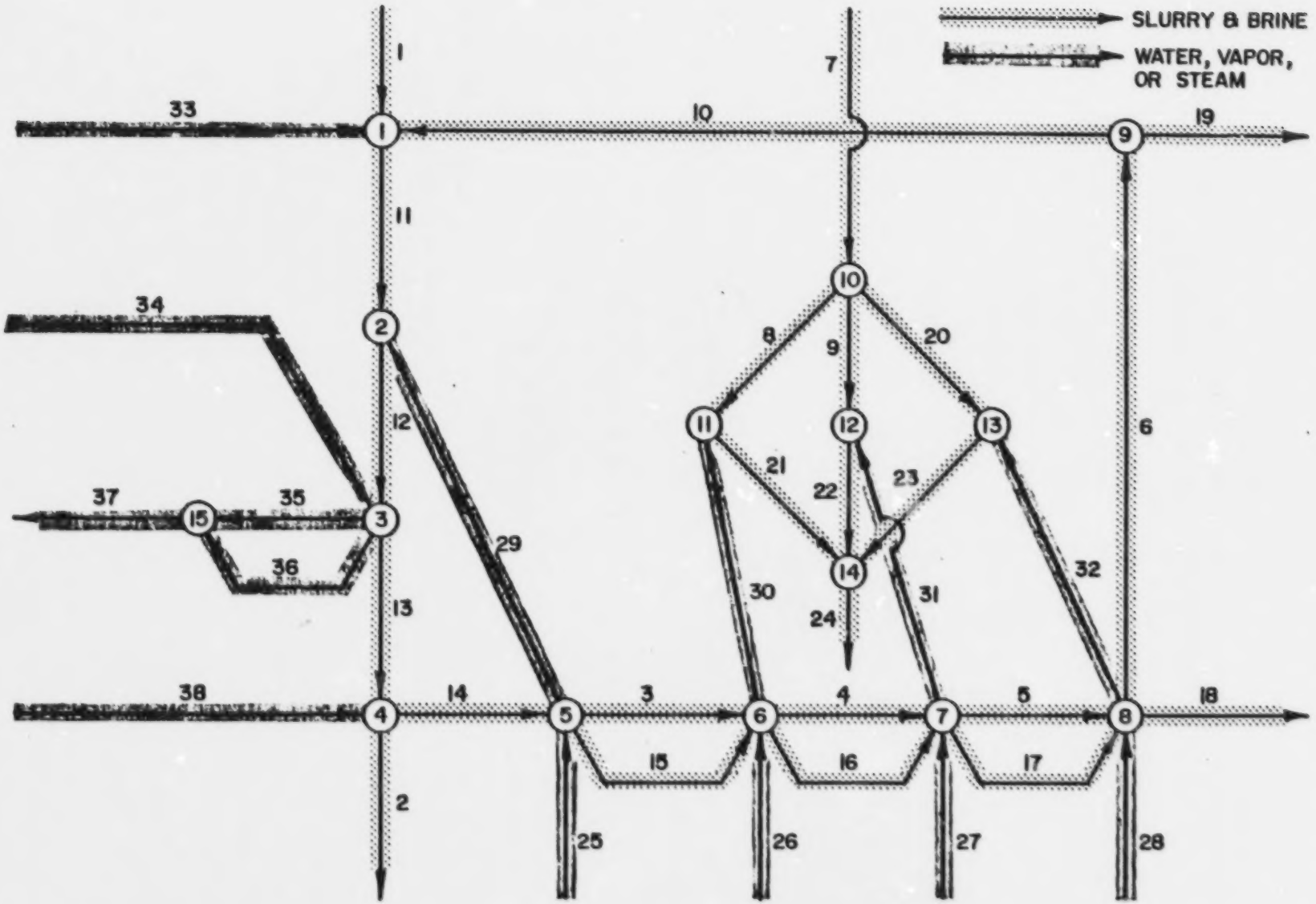


FIGURE II

3.2.2 Node 2 - Preheater

The preheater is a barometric condenser which contacts overhead vapour from the first evaporative crystallizer with the oversaturated discharge (solids present) from the dust mix tank. This contact serves two purposes:

- heat recovery through the partial dissolution of the feed slurry
- condensation of vapour from the first effect

This node is the junction of the minor process recycle.

3.2.3 Node 3 - Dissolvers

The dissolvers consist of two sets of three components. These are:

- Heat Exchanger
- Agitation Unit
- Condensate Unit

Steam at about 127°C and 147 kPa is passed over the shell side of a counter-current heat exchanger. Slurry flows through the tube side as a recycle to the agitation unit. Material from the preheater enters at the bottom of the exchanger unit and discharges at the top of the agitation unit.

Condensate is trapped in the condensate unit and recycled to the boiler units. Normally only one dissolver set is in use at any given time.

3.2.4 Node 4 - Slimes Thickener

This unit serves to clarify the discharge from the dissolvers in order to provide a hot clear brine to the first "effect" of recrystallization. Insoluble slimes settle through flocculation in this thickener and the underflow is withdrawn to tailings disposal.

Ideally, the overflow should be saturated but in practice this is not so due to the lack of on-line analysis and control. The overflow is kept undersaturated to prevent recovery losses and operating problems.

3.2.5 Node 5 - 1st Stage Crystallizer ("1st Effect")

Figure III shows a diagram of one of the four crystallizer units at Central Canada Potash. The first effect differs in that there is a single input from the slimes thickener overflow.

In each unit a vacuum is created by the drawing of vapour by steam ejectors isolated from the crystallizers by barometric condensers (see nodes 2, 11, 12, 13). The boiling crystal suspension is further agitated and mixed through recycle.

A zone of KCl supersaturation is created which is conducive to the nucleation and growth of crystals.

The process of crystallization results primarily from the cooling caused by evaporation and secondarily from concentration of the solution through evaporation itself. Thus it is described as barometric evaporative cooling.

3.2.6 Nodes 6, 7 and 8 (2nd, 3rd and 4th "Effects")

These units are functionally identical. Each unit, however, operates on a progressively higher vacuum and progressively lower temperature. Two slurry streams interconnect stages 1 and 2, 2 and 3, and 3 and 4. At the upper extremity of each lower vessel relatively clear slurry stream passes forward to the next stage. From the base of each lower vessel a slurry of higher percentage solids passes forward to the next stage. From the fourth and last stage this is the product slurry which is centrifuged to yield a product for drying.

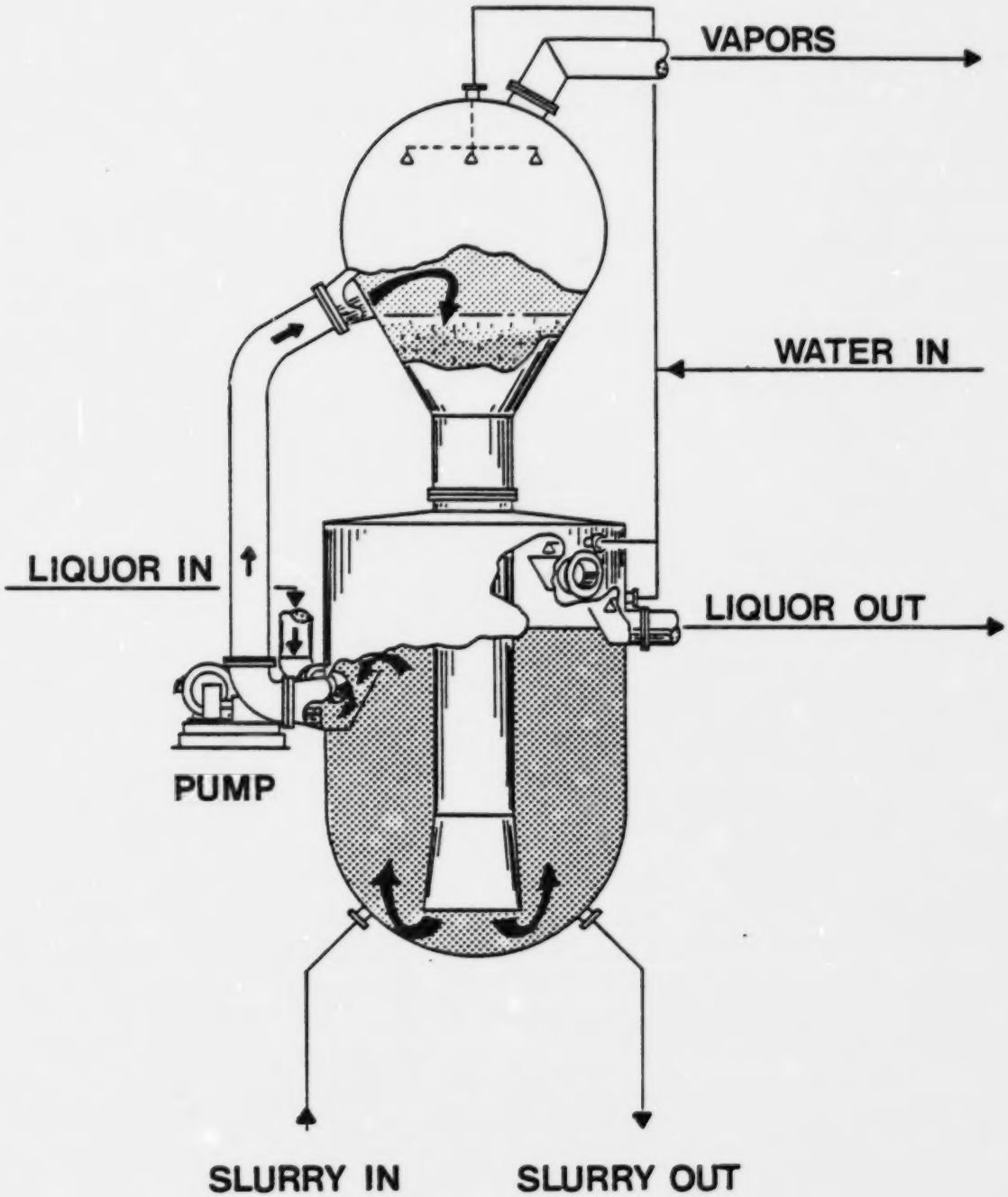


FIGURE III
STAGE 2
CRYSTALLIZER

The clearer liquid from the last stage is called lean brine even though it frequently contains a significant percentage of crystalline KCl. This material is recycled to the dust mix tank. (Major Process Recycle).

3.2.7 Node 10 - Reclaim Brine

Brine reclaimed from outside cooling ponds is distributed as coolant to each of three barometric condensers (Nodes 11, 12, 13) which provide vacuum to each of the 2nd, 3rd and 4th effects. In these cases overhead vapour from each crystallizer makes contact with brine coolant and is taken up by the brine coolant from reclaim.

3.2.8 Node 11 - Return Brine

Brine from the barometric condensers that is undersaturated due to vapor take up is returned to the brine cooling ponds. It is not current practice to monitor the tenor and flow of brine from barometric condensers. However, the mass enthalpy balance shows that these measurements are important to the determination of process state.

3.2.9 Node 15 - Condensate Trap

This node is a portion of the dissolver unit. Its topological creation serves to model the heat exchange process and enables an accurate means of coupling enthalpy to flow throughout the circuit.

4.0 COHERENT MASS ENTHALPY BALANCING

4.1 TOPOLOGICAL ANALYSIS OF THE CENTRAL CANADA POTASH CIRCUIT

The use of topology (a branch of combinational mathematics) was recently introduced by Houdin and Laguitton (1) for the mass balancing of networks in mineral processes. By describing the process as a network of streams connecting nodes this technique produces the network equivalent of the Central Canada Potash circuit as shown in Figure II. Furthermore, the network can be described algebraically in terms of what Houdin calls an incident matrix.

This matrix called m_1, consists entirely of the values 0, 1 and -1.

The convention is very simple:

- if a stream flows into a node the (incident) matrix element is 1
- if it exits the node it is -1
- if there is no connection the element is 0

Consequently, the entire circuit consists of n_q nodes and n_p streams and is represented by an $n_q \times n_p$ matrix m_1. Following usual conventions the row index i (nodes) and the column index j (streams) are introduced.

Further let m denote the following species index:

m	
1	undissolved NaCl
2	undissolved KCl
3	dissolved NaCl
4	dissolved KCl
5	water

which describes the composition of all process streams. (Note the presence of Mg and insoluble material will be treated as a perturbation of enthalpy, where necessary, in order to reduce problem dimensionality).

The following notation will be used for process variables:

D_j	tonnes/hr of solids in solution plus suspension for the jth stream
D_j^w	tonnes/hr of water in the jth stream
D_j^p	tonnes/hr of slurry
z_{mj}	wt fraction of species m in the jth stream
h_{mj}	specific enthalpy of component m in the jth stream Kjoules/hr/kg
$d_j = D_j / D_1$	feed normalized solids flow in the jth stream
T_j	temperature (°C) for the jth stream
ρ_j	specific gravity of the jth stream
ρ_j^b	specific gravity of brine in the jth stream
ρ_s	specific gravity KCl = 1.984 as a solid in lean liquor
S_j	% solids in suspension in stream j
$\delta_j = D_j^w / D_j$	dilution on the jth stream
P_j	pressure of the stream j environment

4.1.1 Conservation Relations

In any bounded physical process matter and energy must be conserved at points of contact or exchange. For matter the conserved quantity is mass and for energy this is enthalpy in the case of a potash circuit.

Enthalpy is by definition:

$$H = U + PV$$

where U is the internal energy and PV is the pressure volume work in change of state. Since process units are insulated and to a good approximation operate at constant internal pressures, energy and hence enthalpy is conserved.

Furthermore, the NaCl-KCl-H_2O system yields the following relationship for the composite enthalpy H.

$$H_j = D_j \sum_m h_{mj} z_{mj} \qquad (1)$$

A statement of equation (1) is that the stream composite enthalpy of the jth stream is the component enthalpy of the mth species multipled by the mass of that constituent summed over all species.

Therefore, in this formulation we have:

Conservation of Mass

$$m_1 D = 0 \qquad (2)$$

where the incident matrix m_1 has been introduced as has the and the diagonal matrix $\bar{D}$ consisting of diagonal elements also

Conservation of Energy

$$m_1 \bar{D}^{\bullet} Z^T h = 0 \qquad (3)$$

Equation (3) contains the transposed matrix Z^T multiplied by the pulp flow matrix $\bar{D}^{\bullet}$. h is principally a function of temperature. Consequently, the conservation of energy yields a nonlinear relationship.

Conservation of NaCl and KCl

In the subsequent development of the mass enthalpy balance the streams of the process network will be numbered in a particular way. All slurry streams will be counted first and the numbering beginning with stream 1 will be such that the incident matrix will be of the following form:

$$m_1 = \begin{pmatrix} m_2, & m_w \\ m_3, & m_4 \end{pmatrix}$$

$$m_2 = (m_5, m_6)$$

m_2 will consist of nodes and streams pertaining only to slurry and brine m_w will apply only to water streams. m_3 will apply only to water nodes and m_4 will apply only to water nodes and water streams.

m_6 will be a lower triangular matrix, i.e. one in which all elements above the diagonal will be zero and all elements on the diagonal will be nonzero.

m_2 is called the brine-slurry incident matrix and the conservation of solids will satisfy the relationship

$$m_2 D = 0 \qquad (4)$$

Equation (4) can be written

as $$m_5 D^B + m_6 D^A = 0$$

where $$D^B = (D_1, D_2, \cdots D_r)$$

constitutes a subset of independent mass flows.

Given a set D^B it is possible to determine the remainder of the set $$D^A = (D_{r+1}, \cdots D_{n_p})$$

by the relationship

$$D^A = - m_6^{-1} m_5 D^B \tag{5}$$

This relationship will be used frequently in the balancing or optimization that will be described later.

Solids can be present in solution or undissolved form. Relations such as

$$m_2 D (Z^T_{k+m} + Z^T_k) = 0 \tag{6}$$

must be satisfied where k takes the values 1 and 2 and M has the value 2. This relationship will balance the total levels of NaCl and KCl around the circuit. Moreover, it will follow that

$$\sum_{k=1}^{5} Z_k = 1 \tag{7}$$

It can be shown that relations (6) and (7) are superfluous when energy and mass are in balance. This creates a problem in the numerical analysis called degeneracy. It will be resolved later.

4.1.2 Solution Chemistry

The solubility curves for the NaCl-KCl-H_2O system are shown in Figure V. Two families of curves connect on a curve called the joint saturation curve. This is the set of conditions where the solution is saturated with respect to both NaCl and KCl. In a crystallizer this condition rarely exists. Throughout the circuit a condition of undersaturation exists with respect to NaCl. These are the Z_2 curves which lie below the joint saturation curve in Figure V.

The phase or solution chemistry consists of a constraint equation

$$Z_{k+m} = \chi_k(T, Z_{M+m}) \quad m \neq k \qquad (8)$$

which must be satisfied and this is one of the major complications in mass enthalpy balancing.

4.1.3 A Coherent Balance

Process measurements fall into several categories:

D_{oj}^{p} pulp flow measurements

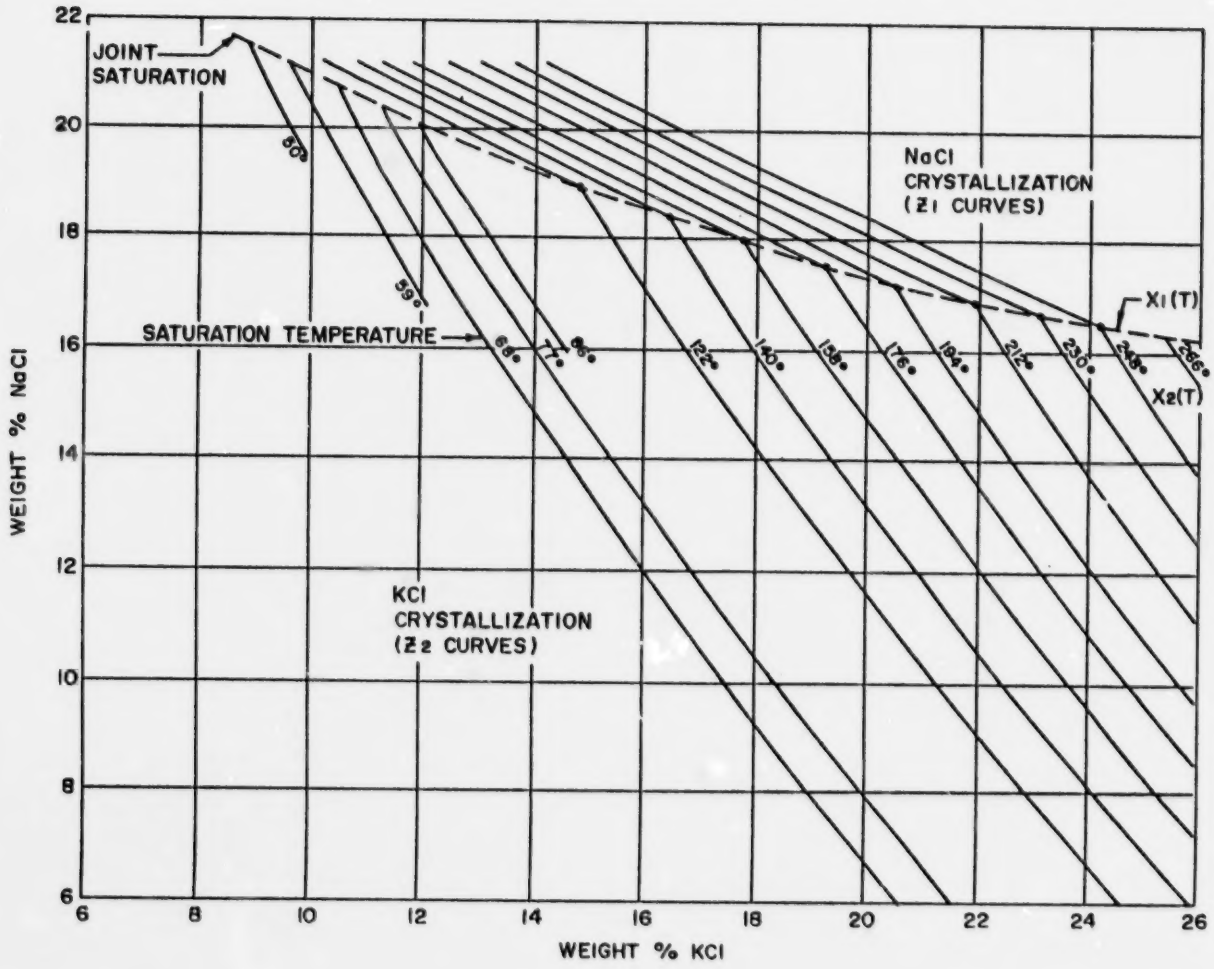
D_{oj}^{w} water flow measurements

a_{mj} analysis measurements

δ_{oj} dilution or density measurements

T_{oj} temperatures

SOLUTION CHEMISTRY KCl-NaCl-H_2O SYSTEM



JOINT SATURATION

$Z_3 = X_1(T)$

$Z_4 = X_1(T)$

KCl PRECIPITATION

$Z_4 = Z_2 (T \mid Z_3)$

NaCl PRECIPITATION

$Z_3 = Z_1 (T \mid Z_4)$

GENERAL RELATIONSHIP

$Z_3 \leq X_3 (T \mid Z_m)$

$Z_4 \leq X_4 (T \mid Z_m)$

OR

$Z_{M+k} \leq X_k (T \mid Z_{M+m})$

FIGURE V

Pressures that are measured can be reduced to equivalent temperature measurements. Associated with each of the above measurements it is convenient to introduce the statistics

$$\sigma_j^p,\ \sigma_j^w,\ \sigma_{mj},\ \sigma_j^\delta,\ \sigma_j^T$$

which represent the accuracy or uncertainty of the associated pulp, water, analysis, dilution or temperature measurements.

The following quadratic form will introduce the notion of a coherent balance:

$$J = \sum_j \left(\frac{D_j^p - D_{oj}^p}{\sigma_j^p}\right)^2 + \sum_j \left(\frac{D_j^w - D_{oj}^w}{\sigma_j^w}\right)^2 + \sum_j \left(\frac{\delta_j - \delta_{oj}}{\sigma_j^\delta}\right)^2 + \sum_m \sum_j \left(\frac{z_{mj} - a_{mj}}{\sigma_{mj}}\right)^2 + \sum_j \left(\frac{T_j - T_{oj}}{\sigma_j^T}\right)^2 \tag{9}$$

subject to:

$$\begin{aligned} & m_1 D = 0 \\ & m_2 D^p = 0 \\ & m_2 \bar{D}^p (z_k^T + z_{k+m}^T) = 0 \\ & m_1 \bar{D}^p z^T h = 0 \\ & z_k \le X_k (T, z_{l \neq k}) \\ & \sum z_k = 1 \end{aligned} \tag{10}$$

A coherent balance is a set of flows analysis and temperatures that minimizes the functional J in equation (9) while satisfying the constraints in equation (10).

The problem so described is known as a mathematical program and there exists no direct method of obtaining a solution.

The problem must be segmented in order to obtain a solution. Each segment must be linearized in some way as well. This segmentation is illustrated in Figure VI as being one way of obtaining a solution.

The procedure so described is called hierarchical optimization because several segments of the overall problem are solved in a hierarchical order.

4.2 SEGMENTED PROBLEMS

4.2.1 The Water Balance

The following problem is suboptimal to the overall problem:

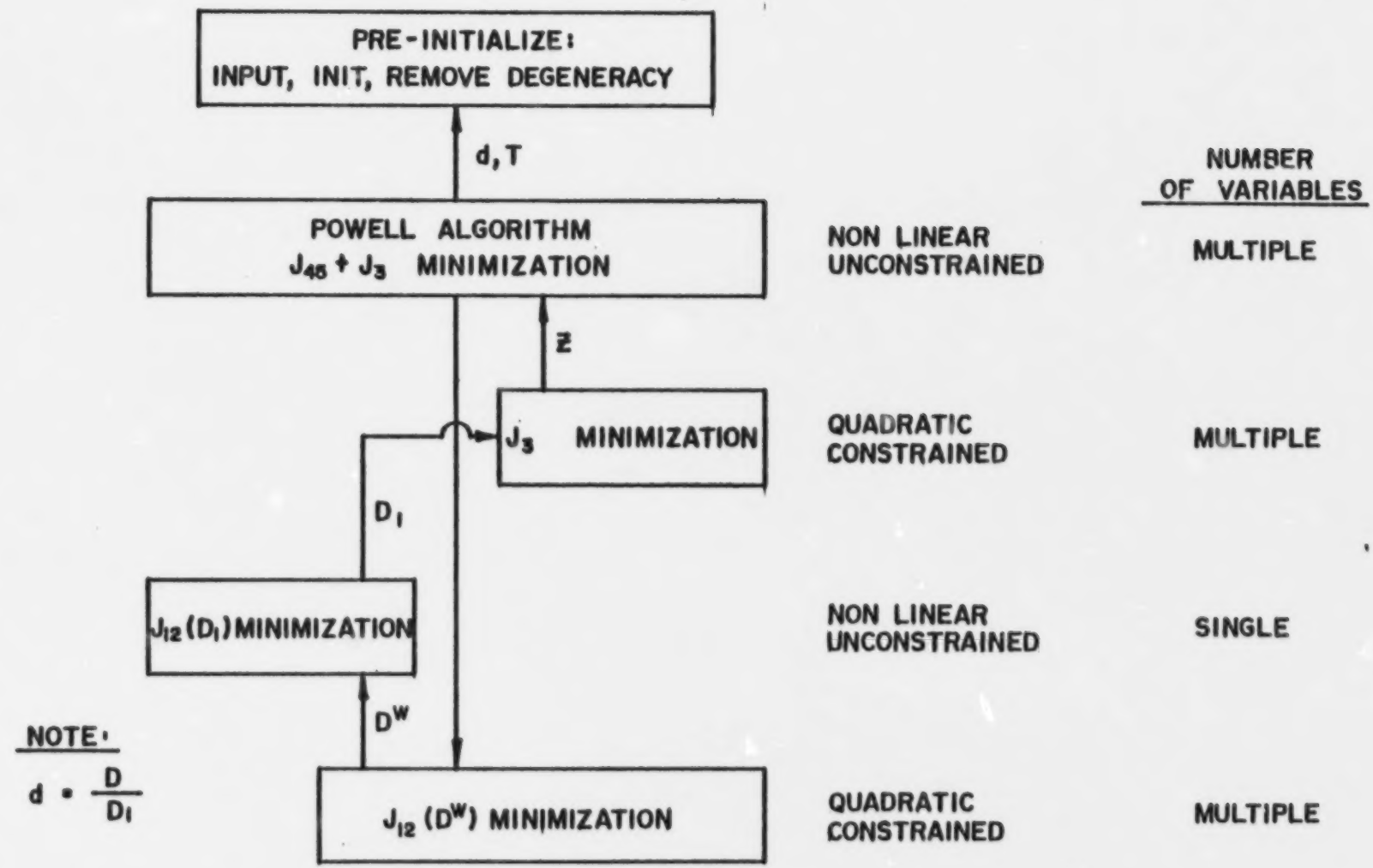
$$\min \quad J_{1,2} = \sum_j \left(\frac{D_j^a - D_{oj}^a}{\sigma_j^a} \right)^2 + \sum_j \left(\frac{D_j^w - D_{oj}^w}{\sigma_j^w} \right)^2 + \sum_j \left(\frac{\delta_j - \delta_{oj}}{\sigma_j^\delta} \right)^2 \quad (11)$$

subject to:

$$m, D^w = 0 \quad (12)$$

HIERARCHICAL MINIMIZATION

$$\underset{d,T,\bar{z},D,D^W}{\text{MIN. } J} = \underset{d,T}{\text{MIN.}} \left[J_{45} + \underset{\bar{z}}{\text{MIN.}} \left(J_3 + \underset{D_1}{\text{MIN.}} \underset{D^W}{\text{MIN.}} J_{12} \right) \right]$$



NOTE:

$$d = \frac{D}{D_1}$$

FIGURE VI

since $$D_j^P = D_j + D_j^W$$

and $$\delta_j = \frac{D_j^W}{D_j}$$

J_{12} can be shown to be a quadratic in D^W, i.e.

$$J_{12} = (D^W)^T U D^W - 2WD^W + T \qquad (13)$$

where U is a diagonal matrix and W is a vector and T is a scalar all of which are independent of D^W.

However, J_{12} can be shown to be a function of D_1 the solids feed to the circuit.

$$U_j = \frac{1}{(\sigma_j^\delta)^2 d_j^2 D_1^2} + \frac{1}{(\sigma_j^P)^2} + \frac{1}{(\sigma_j^W)^2} \qquad (14)$$

$$W_j = \frac{1}{(\sigma_j^\delta)^2 d_j D_1} + \frac{D_{aj}^P - d_j D_1}{(\sigma_j^P)^2} + \frac{D_{aj}^W}{(\sigma_j^W)^2}$$

$$T = \sum_j \frac{d_j^2 D_1^2 - 2 d_j D_1 D_{aj}^P}{(\sigma_j^P)^2} + \sum_j \left[\frac{(D_{aj}^P)^2}{(\sigma_j^P)^2} + \frac{(D_{aj}^W)^2}{(\sigma_j^W)^2} + \frac{(\delta_{aj})^2}{(\sigma_j^\delta)^2} \right] \qquad (15)$$

It can be shown that J_{12} will be minimum for the value $\hat{D}^W$ given by:

$$\hat{D}^W = U^{-1} W - U^{-1} m_1^T (m_1 U^{-1} m_1^T)^{-1} m_1 U^{-1} W \qquad (16)$$

Moreover $\hat{D}^w$ will be strictly a function of the single parameter D_1 if all of the d_j are held constant. It was explained earlier that the D_j and hence the d_j derive from an independent subset $(D_1 \cdots D_t)$. In addition, the complete set D_j follow from equation 5.

4.2.2 The Analysis Balance

The functional:

$$J_3 = \sum_m \sum_j \left(\frac{z_{mj} - a_{mj}}{\sigma_{mj}} \right)^2 \tag{17}$$

can be minimized with respect to z_{mj} and subject to:

$$m_1 \bar{D}_j^b z^T h = 0 \tag{18}$$

$$m_2 \bar{D}_j^b (z_k^T + z_{k+m}^T) = 0 \tag{19}$$

$$\sum_{k=1}^{5} z_k = 1 \tag{20}$$

$$z_{k+m} \leq x_k (T_j, z_{m+M}) \quad M \neq k \tag{21}$$

Constraint (21) is an enormous complication with regard to obtaining solutions. In this study relation (21) was eliminated from the constraint set on the solution z_{mk} and reintroduced as extra conditions in the error model for determining σ_{mj} values. In effect, constraints (21) come into play only in situations where they can bind the solution. Reintroducing them into the error model in this way avoids mathematical complications yet will force the solution to respect the solubility constraints (equation 21).

The analysis problem can be regarded as the minimization of J_3 subject to a constraint matrix C.

$$C z = e$$

This constraint matrix is developed by using the pulp flow vector D^* based upon the current values of D and D^W after having performed a water balance and further minimization with respect to the feed variable D_1.

During the program development it was decided to check the rank of the matrix C. It was shown to have less than full row rank. Indeed the row rank was found to be less than full by an amount precisely equal to the number of streams. The obvious conclusion was that the relation:

$$\Sigma z_k = 1$$

was redundant.

Consequently, the above constraints were dropped from the analysis yielding a constraint matrix that would have full row rank. However, analysis balancing would yield solutions with slack in the water analysis of each stream. Eliminating the water slack would be accomplished at the next highest level of optimization in the hierarchy.

4.2.3 Mass Balancing

The last and highest level of optimization is the determination of the value D which influences the lower balances (water and analyses). Mathematically it can be described by:

$$\min_{D} \left\{ \min_{z} \left\{ J_3 + \min_{D_1} \left\{ \min_{D^W} J_{1,2} \right\} \right\} \right\}$$

This minimization is effected in two ways:

- A starting value for D is obtained by successively substituting values of D^W that will remove the water slack from the J_3 problem followed by,

- The refinement of D using the Powell algorithm supplied by D. Laguitton of E.M.R.

The first step usually guarantees convergence and helps to avoid the excessive expenditure of computer time in the Powell algorithm.

4.2.4 Temperature Equilibrium

In certain circumstances it may be desirable to balance to one further level. This would be a variation of T_j the stream temperature, to minimize :

$$J_{4S} = \sum_j \left(\frac{T_j - T_{0,j}}{\sigma_j^T} \right)^2$$

This provides an estimate of thermodynamic equilibrium. However, such a computation is very expensive in computer time.

A compromise solution can be obtained by variation of temperatures only for those streams showing residual water slack (or node water imbalance),

$$z_j = 1 - \sum_k^{\mu} z_k$$

after the completion of overall J minimization.

5.0 COMPUTATIONAL PROBLEMS AND THE PROCESSING OF CENTRAL CANADA POTASH DATA

5.1 PRELIMINARY TESTING

The first level of program testing was with a very simple and highly idealized potash circuit which consisted of a cyclone, a water addition unit and a combination tank.

This trivial process provided a means of testing 85% of the program logic of the COMEBAL system. This testing revealed an important problem relating to the mathematical method. This was the problem of degeneracy due to the numerical identity of the relations:

$$\Sigma z_m = 1$$

$$m_2 \bar{D}^b (z_k^T + z_{k+m}^T) = 0$$

if D^b satisfies

$$m_1 D^b = 0$$

The first equation had to be removed from the so-called J_3 problem where enthalpy and species (KCl, NaCl) conservation is involved.

However, by leaving out the consistency equations one cannot guarantee that they will be satisfied. Indeed, in a practical situation it proved necessary to satisfy consistency by adding a term representing nodal water imbalance to the overall J minimization.

$$\sum_m \sum_k W_{mk}^2 \left(1 - \sum_m z_{mk}\right)^2$$

The weights W_{mk} were derived from the σ_{mk} which relate to the analysis measurements a_{mk}. Alternatively, they can be set at such high levels as to guarantee satisfaction.

However, the former made more sense from a statistical mechanical point of view because it spreads the statistical imbalance of measurements over the energy and mass functions in a uniform way. Thus what appeared at first to be a major computational problem led to a model refinement.

Final program checkout had to deal with other mathematical and computational problems concurrent with the analysis of the Central Canada Potash data.

5.2 DIMENSIONALITY AND PROGRAMMING CONSIDERATIONS

The COMEBAL system, in total, consists of 1852 program statements. Of this total some 1300 were written and tested by Kilborn over the period of the CANMET Study. The programming period occupied 50 man days. Consequently, a productivity of 26 statements (debugged) per man day was achieved.

The system was developed with the constraint that it operate in a 256K region of an IBM computer. The SASKCOMP computer (an IBM 4341) in Saskatoon was used. In addition, it was deemed worthwhile to follow the programming standards established for the CANMET SPOC program. It was further required that SI (metric) units be used throughout.

COMEBAL is a modular system and 60% of the modules are useful stand-alone components that will compliment the SPOC library for potash users of the SPOC technology.

Since COMEBAL is based upon matrix algebra and topology its data base and data storage consist of arrays of data. Although FORTRAN has programming aids for storing and manipulating arrays, this method of array storage was rejected in favour of a compressed method.

This introduced immense program checkout difficulties but will enable the incorporation of a version of COMEBAL into a process control "black box". This would be a micro-computer having at least 256K of RAM and special hardware for matrix and floating point arithmetic. The micro would be able to perform the computation of several coherent mass enthalpy balances per shift in a plant thus providing an important prerequisite for on-line optimal control of a potash crystallizer or a dryer/cooler circuit.

5.3 THE PROBLEM OF CONVERGENCE

The COMEBAL System was constructed on the basis of a three level hierarchy of computation. From low to high in the hierarchy these three levels are:

Level 3 - Water and Feed Balance
Level 2 - Enthalpy and Analysis (NaCl, KCl) Balance
Level 1 - Relative Solids Flow, Consistency and Temperature Balance

Each level involves the minimization of a portion of the least squares functional J shown in equation (9).

A problem has arisen due to the slowness of the convergence at level 1 where the most nonlinear portion of the least squares functional is housed. So far the computing budget has prevented complete convergence.

At the final stage of the current phase of this project a better way has been suggested.

This would involve the replacement of the J_3 minimization

$$J_3 = \min (\underline{z}-\underline{a})^T V^{-1} (\underline{z}-\underline{a}) \qquad (22)$$

with

$$J_3^* = \min (\underline{z}-\underline{a})^T V^{-1} (\underline{z}-\underline{a}) + (D^w - D_o^w)^T U^{-1} (D^w - D_o^w) \qquad (23)$$

where $u_j = (\sigma_j^w)^2$

The constraints in the J_3 problem are

$$m_2 \bar{D}^p z^T h = -m_2^w h^w D^w$$
$$m_2 \bar{D}^p (z_k^T + z_{k+m}^T) = 0 \qquad (24)$$

where

$$m_1 = \begin{pmatrix} m_2 & m_2^w \\ 0 & m_3^w \end{pmatrix}$$

is a simple decomposition of the network incident matrix into a slurry brine incident matrix M_2. The matrix M_2^w is the M_1 incident matrix corresponding to slurry brine nodes and water streams and M_3^w corresponds to water nodes and water streams.

In the case of the Central Canada Potash circuit there is only one water node. This is the dissolver condensate trap.

The constraint matrix for the J_3^* minimization would be

$$m_2 \bar{D}^p z^T h + m_2^w h_w \bar{D}^w = 0$$
$$m_3^w h^w \bar{D}^w = 0$$
$$m_2 \bar{D}^p z_s + m_2^w \bar{D}^w = 0 \qquad (25)$$
$$m_3^w \bar{D}^w = 0$$

The above set of constraints would give greater degrees of freedom to the enthalpy balance and at the same time reintroduce consistency at the analysis balance stage. This reduces the optimization burden [illegible] level 1 where the computationally onerous POWELL algorithm executes.

This approach was considered early on in the project but was rejected because it required a J_3^* problem containing a larger number of equations. In the case of the Central Canada Potash circuit it would increase the number of equations from 42 at the J_3 step to 78 or 250% more computer time at that step. However, it has proven to be a false economy and the COMEBAL system will be revised to introduce J_3^* in place of J_3.

5.4 REVIEW OF THE CENTRAL CANADA POTASH DATA

Table I in Appendix A shows a coherent mass energy balance on the Central Canada Potash circuit. This was obtained as a result of the sampling of temperature, flow, density and analysis, over a relatively short time period. The sampling period was chosen at a time when the circuit was thought to be reasonably stable.

The mass enthalpy balancing procedure was complicated by the fact that the computer system had to be given final debugging through the use of the Central Canada Potash data.

Also at question was the level of measurement accuracy that should be pursued. Since one of the goals of mass energy balancing is to provide an answer to the question of measurement accuracy, no great attempt was made to pursue high accuracy.

Indeed, it appears that there are certain areas where improvement in instrumentation must occur before the full benefit of the mass enthalpy balancing can be obtained.

5.4.1 Density Measurement

The data reported by Central Canada Potash provided a measurement of density throughout the circuit which is ± 2.7 volumetric percent solids.

This error adds to the effectively large σ error for KCl in the stream where the density measurement is required.

An examination of saturation conditions even in the dissolver and thickener showed undersaturation with respect to NaCl In this case there is less definition of the KCl statistic on the stream unless density has a higher measurement accuracy than that reported.

5.4.2 Temperature Measurements

Accuracy was $\pm$2°F for most streams. This is quite acceptable for mass energy balancing. However, there was no measurement of steam temperature and pressure that could be assigned as being representative of condensate condition.

5.4.3 Flow Measurements

The balance shows that water flow measurement accuracy is acceptable. However, brine and slurry measurements were not sufficiently good to provide clear insight into circuit performance. It is quite evident that greater accuracy will be a prerequisite for future work.

The extent of instrumentation around the barometric condensers needs to be improved. Knowledge of the flow of brine to each barometric condenser would help to give better definition to the amount of evaporation from each effect.

Flow was measured on each underflow slurry stream. The amount that was actually being passed forward had to be determined by using the measured flow in a line while an uncertain percentage cycled back to each effect. The difference was the amount fed forward.

5.5 GENERAL COMMENTS

During the sampling campaign it appears that very little insol was present in the feed. Also the amount of water being added to depress any NaCl precipitation in the dissolvers was substantial. The suggestion is that the circuit could be operated closer to joint saturation in the dissolvers, thereby reducing energy costs.

The circuit shows a delayed transient in the third and fourth effects. Only fourteen hours had elapsed since a major feed change had occurred. Consequently, an anomalously high solids concentration showed at the time of measurement.

Because the computer system was under test while the Central Canada Potash data was being analysed it was possible to observe the process of solution. In particular the convergence toward the establishment of a coherent balance was displayed. This has given considerable insight into how the system behaves dynamically.

Balancing appears to be favoured at higher rather than lower production rates. Convergence accelerates at high feed rate and imbalances which are mathematically similar to driving forces are diminished. It is suggested that crystallizer circuits might operate well at higher rates and this should be explored in future studies.

6.0 ANALYSIS OF THE COHERENT BALANCE

6.1 GENERAL OBSERVATIONS

The balancing has yielded a number of absurdities Mostly these are negative water flows. However, the occurrence of these negative water flows is associated with the delayed transient that obviously is present. Moreover, the negative water flow is easily resolved if a parallel stream is averaged with the stream showing the negative water flow. The overhead vapor from the third stage is also negative. This too is an indication of the delayed transient.

Another absurdity is the composition of new material. It shows a negative amount of NaCl in solution. It is not clear why this happens.

Two explanations arise:

- NaCl measurements are consistently in error.
- The new material and discard brine streams can and should be averaged in some way.

The latter is the most plausible explanation. Central Canada Potash were unable to estimate the composition of the new material and although there was no discard brine during the measurement campaign, the negative NaCl in new material would be resolved if substantial discarding of brine had occurred prior to the sampling period.

Performing simple propogation time calculations based upon unit retention times shows that an enthalpy wave was established by a change in feed approximately fifteen hours before. At the rate that water was being added a cycle would

persist unless considerable quantities of brine were to be purged at some time say four to ten hours after the time that measurements were taken.

The amount of brine being employed to condense overhead vapour from the last three effects is considerably in excess of energy requirements. It has been the contention of some operating managers that crystallizers could operate well with lower coolant flows to barometric condensers. The mass energy balance tends to confirm this.

The thoughtful examination of the coherent balance shows that considerable operating knowledge is required in order to interpret results. Moreover, it is abundantly clear that several iterations of sampling and mass enthalpy balancing are required in order to unravel the control mysteries of a multi-stage crystallizer.

Again it must be emphasized that computer run costs did not allow the J minimization to proceed to final convergence. There is a strong suggestion that the high KCl solids concentration shown on the product stream would have been diminished if the computation had been allowed to go to full convergence.

6.2 SATURATION CONTROL

In order to avoid NaCl fouling in the dissolver heat exchanger it has become the practice to add water at the dust mix tank. This is being done not only at Central Canada Potash but also at Cominco.

When water is added to a crystallizer additional energy must be supplied to crystallize product. The balance reflects that this practice may be excessive.

7.0 OPTIMAL CONTROL OF CRYSTALLIZER CIRCUITS

7.1 INTRODUCTION

The optimum control of a crystallizer will be based upon a different objective function for different plants. However, energy control will be a common denominator. In this study it was determined that the critical issue in energy control is the dampening of energy wasteful effects that accompany disturbances. A control strategy to do this will involve:

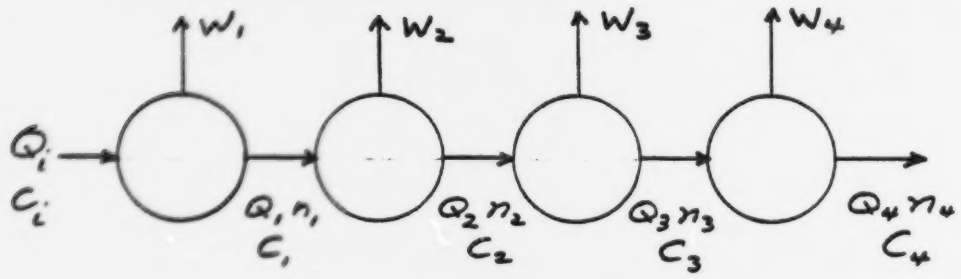
- An ability to identify the state of the process.

- An understanding of dynamic effects.

Critical to the first point is mass energy balancing. Dynamic effects are governed principally by the processes of crystal nucleation and growth.

The following deals with the understanding of crystal growth and the role mass energy balancing. Beyond this the question of minimal measurement set and required accuracy are examined.

7.2 CRYSTAL GROWTH IN A POTASH CIRCUIT AND THE USE OF A COHERENT MASS ENERGY BALANCE



The above is a symbolic representation of a coherent mass enthalpy balance in the Central Canada Potash crystallizer circuit.

$$Q_i \qquad Q_k \ (k=1,4)$$

represent the aggregate volumetric flow rates for lean brine plus interstage slurry in m^3/hr.

C_i / C_k is the concentration of KCl solids in suspension in the above streams expressed as Kg/m^3

W_i are the overhead vapour flows less the quench water added (add back water) in m^3/hr (water basis)

An additional item of information at each stage might be available. This is the particle size distribution

$$n(L,t)$$

The crystallization process is governed by the partial differential

$$\frac{\partial n}{\partial t} + G\frac{\partial n}{\partial L} + \frac{h(L)n}{\tau} = 0$$

subject to

$$B^{\circ} = k_N S^I M_{kj}$$

as a boundary condition.

h(L) is a product removal function

S is the level of supersaturation of the magma in the crystallizer

k_N is a rate constant

G is the crystal growth rate which is independent of particle size

M_{kj} is the Jth moment of the crystal population (defined later)

These equations describe the dynamics of the crystal growth process.

7.3 THE COHERENT MASS BALANCE

An important observation should be made at this point. This observation is that having obtained a coherent mass balance, the cyclical relationship inherent in the circuit has been removed from an analytical point of view, if it is desired to explore the dynamics of the crystal growth process.

Moreover we have a means of computing the quantity

$$F = G\frac{\partial n}{\partial L} + \frac{h(L)n}{\tau}$$

which might be called the driving force for crystal nucleation and growth. The practical use of this function as a means for determining and identifying nonstationary behaviour is illustrated in the following analysis.

Coherent mass energy balancing provides a means of identifying stationary behaviour $\frac{\partial n}{\partial t} = 0$

Under these circumstances crystal nucleation and growth are governed by the ordinary differential equation (ODE).

$$G\frac{dn}{dL} + \frac{h(L)n}{\tau} = 0$$

7.4 MOMENT FORM OF THE POPULATION BALANCE

Introducing the notion of CSD moments (Crystal Size Distribution)

$$m_{kj} = \int_0^\infty n_j L^k dL$$

it can be shown that

$$m_{kj} = m_{kj-1} + k G_j \tau m_{k-1,j}$$

and

$$m_{0j} = m_{0j-1} + \tau B_j^\circ$$

The significance of this is that a particle size analyser of the diffraction type measures moments m_{kj} rather than the distribution n_j itself. Moreover, in moment form the system field equation is algebraic rather than differential.

Crystallizers of the type used at Central Canada Potash have the withdrawl function

$$\frac{h(L)n}{\tau} = \frac{Q_j n_j}{V_j} - \frac{Q_{j-1} n_{j-1}}{V_{j-1}}$$

where V_j is the crystal suspension volume in the jth unit.

The process is controlled so that $\frac{Q_j}{V_j} = \tau$ and the population balance becomes

$$G_j \frac{dn_j}{dL} + \frac{(n_j - n_{j-1})}{\tau} = 0$$

except for the first effect where

$$G_1 \frac{dn_1}{dL} + \frac{n_1}{\tau} = 0$$

In conclusion, it has been shown that there exists a means of computing the growth and nucleation parameters in the Central Canada Potash crystallizer provided that there is:

- a means of determining steady state operation (equilibrium)
- a means of particle size analysis

Knowledge of growth and nucleation parameters enable the use of driving force equations for analyzing dynamic and quasi-stationary behaviour.

7.5 DEFINING A MINIMAL MEASUREMENT SET

An interesting analysis of the coherent balance at Central Canada Potash results from the lumping together of the last three stages of the Central Canada Potash as a single unit.

Topologically this makes sense and moreover, most of the internal absurdities average out (negative overhead vapor from the third effect).

From a cost of instrumentation point of view this also makes sense. (Analysis and particle size probes are expensive). The following is a suggested list of measurement points and the associated measurements for the effective use of a COMEBAL "black box".

Dust Mix Tank Discharge	F, Z
Hot Thickener Underflow	F, Z
Feed to First Effect	F, Z
Lean Brine to 2nd Effect	F, Z, n
Crystallizer Product	F, Z, n
Recycle Brine	F, Z, n
Discard Brine	F
Reclaim Brine	F
Return Brine	F

The symbol F represents volumetric flow.

Z represents the trio (Z_N, Z_k, S)

where Z_N is the percentage NaCl in the stream by weight

Z_k is the same for KCl

S is the % solids by volume in the suspension

n represents the moments of the particle size distribution or the distribution itself

On-line x-ray fluorescent analysers are not capable of measuring NaCl because of the low atomic number of Na. It can be measured off line in a plant laboratory. K^{40} analysers measure only KCl.

In the absence of NaCl measurements it would be sufficient to measure Z_k and S for most streams. In this case the coherent balance will provide a means of estimating Z_N from the solubility diagram.

Flow measurement needs greater attention when planning an instrumentation and control design. Recycle, reclaim and return brine flows and the flow from the dust mix tank become important measurements if mass and energy can be routinely balanced in a crystallizer circuit.

It goes without saying that temperature should be measured wherever possible if not on all process streams.

Density alone is perhaps not a useful measurement. However, it is essentially part of the analytical measurement on slurry streams. When taken in conjunction with flow density becomes a very important and useful indicator for determining the process state.

7.6 ACCURACY REQUIREMENTS

The following is a guide for measurement accuracy:

Flow	±5%
Temperature	±1°C
Analysis	±.3%
Density	±1% solids
Pressure	±5%

Perhaps density is the most difficult measurement insofar as the accuracy requirement is concerned. It is important to note that specific gravity is a poor indicator of density because it hides a wide variation of brine specific gravity in a crystallizer circuit. This is due to dependence upon NaCl level as well as temperature. Elsewhere in a potash circuit the distinction between specific gravity and percent solids is of less importance.

The relationships between volumetric percent solids C_v, weight percent solids C_w and specific gravity ρ are not at all obvious. Significant errors in potash mass balancing are made due to miscommunication and lack of care and attention. Important relations are:

$$\rho = \rho_s C_v + \rho_B (1 - C_v)$$

$$C_w = \frac{\rho_s C_v}{\rho_s C_v + (\rho_s - \rho_B)(1 - C_v)}$$

where ρ_s = 1.984 is the specific gravity of pure crystalline KCl in a brine carrier.

ρ_B is the specific gravity of brine

During the course of this study a formula for ρ_B was developed as a result of measurements performed at the Saskatchewan Research Council.

8.0 CONCLUSIONS AND RECOMMENDATIONS

In conclusion to this report it is possible to summarize the results of this study in the following way:

- Mass enthalpy balancing is crucial to the development of an optimal control scheme for potash crystallizer circuits.

- Mass enthalpy balancing is computationally feasible in an off-line mode.

- On-line mass enthalpy balancing should be possible based upon the availability of a fast microprocessor with a large random access memory and floating point hardware, along with additional process instrumentation.

- It is possible to determine a good estimate of thermodynamic equilibrium in a potash circuit if the statistics of measurement are known and incorporated into a statistical error model.

- Potash crystallizers display transient behavior in which crystallization and solids transport are coupled through process recycle.

- There are indications that this coupling which originates from feed disturbances can be corrected or dampened by the appropriate control action.

- Energy control and saturation control are synonymous in crystallizer circuits.

- The practice of introducing water to prevent NaCl precipitation may be excessive under current practice.

- Crystallizer circuits require additional instrumentation in order to provide a clearer picture of "what is going on in the process".

- Topologically a potash crystallizer circuit should be simplified in order to analyse mass energy relationships. This involves idealizing several crystallizer units as a single unit.

- Coherent mass energy balancing provides a means for estimating the nucleation, growth rate, and supersaturation levels in a potash crystallizer.

- Coherent mass balancing, therefore, can provide a means of modelling and controlling the crystal growth process when used in conjunction with particle size analysers.

The current status of the work completed in this project can be summarized as follows:

- Based upon measurements taken on one plant at a particular time a method of coherent mass enthalpy balancing has been demonstrated.

- The system so developed needs to be refined and made more efficient computationally.

- Its application should be followed up at the example plant and demonstrated at other plants.

- Other aspects of control such as crystal growth and circuit regulation should be explored.

- A detailed plan for the implimentation of on-line optimal control of potash crystallizers should be developed.

- The application of this control methodology should be extended to other potash circuits such as dryer/cooler systems and to the production of industrial minerals and chemicals other than potash.

REFERENCES

1. CANMET Publication MRP-3.4.0.0.01 "Material Balance Computation for Process Evaluation and Modelling"; BILMAT Computer Program.

2. Houdin, D. and Everell, M. D., 1980 "A Hierarchical Procedure For Adjustment and Materal Balancing of Mineral Process Data". International Journal of Mineral Processing; Vol. 7, No. 2, pp. 91-116.

3. Laguitton et al, "Household FORTRAN Computer Program for the Ore Processing Laboratory". Division Report MRP/MSL 80-115 (IR), CANMET, Canada Centre for Mineral and Energy Technology.

APPENDIX A

APPENDIX A

COMPUTATIONAL RESULTS FROM THE ANALYSIS OF THE CENTRAL CANADA POTASH DATA

Table I, consisting of four pages of computer printout, shows the result of five iterations of the POWELL algorthm for overall J minimization.

The table is constructed to show the balance in comparison to measured values. In addition, the statistic σ_x on each measurement is shown along with a number called RATIO

$$\text{RATIO} = ABS\left(\frac{X_{BAL} - X_{MEAS}}{\sigma_x}\right) \times 100$$

Values greater than 200 are considered to be outliers and merit special attention.

For example:

Reclaim brine has a RATIO of 531. From this and other considerations one can conclude that an excessive amount of coolant is being used as feed to the barometric condensers.

Another example of a high RATIO is slurry to stage 2, which also has an absurd water flow.

The interpretation is clear. The measured volumetric flow of interstage slurry is grossly in error. In fact, a larger percentage of interstage lean brine is actually slurry. From the balance one can calculate this amount. Then the lean brine and slurry percent solids come into line along with the water analysis and the interstage flows.

Turning to the Analysis Table portion of Table I and searching for outliers in the same way one comes upon the high percent KCl in the hot thickener overflow and the feed to the first effect. This can be traced back to the heat addition at the dissolvers which is in error as reported to the system. The higher than saturation level of KCl represents a simulation effect approximating the operation of the hot thickener 5°C higher than actual.

A high ratio on product slurry is due to the fact that the balance has not converged completely. The POWELL algorithm works around the circuit and product density is one of the last variables corrected.

In summary, if one proceeds in this way around the circuit and over all the measurements, one concludes that this balance is good enough for the time being. The next logical step is to review the balance with the operating personnel at the plant with the view towards obtaining a more appropriate measurement set (or sets) under different operating conditions.

Also one concludes that there is a need for more rapid and more complete numerical convergence.

FLOW ANALYSIS

STR	DESCRIPTION	WATER FLOW MEAS	WATER FLOW BAL	WATER FLOW RES	WATER FLOW STAT	WATER FLOW RATIO	PULP FLOW MEAS	PULP FLOW BAL	PULP FLOW RES	PULP FLOW STAT	PULP FLOW RATIO	% SOLIDS MEAS	% SOLIDS BAL	% SOLIDS RES	% SOLIDS STAT	% SOLIDS RATIO	S.G.
1	NEW MATERIAL		14.95														
2	HOT TANK U/F		4.50									25.00	96.74	71.74	10.00	717.41	1.9768
3	LEAN BRINE TO STG 2		85.82				3.77	9.95	-6.18	1.51	410.16	5.80	7.43	1.63	2.70	60.46	1.2891
4	LEAN BRINE TO STG 3		75.42									9.70	13.62	3.92	2.70	145.27	1.3434
5	LEAN BRINE TO STG 4		54.37									15.40	21.76	6.36	2.70	235.49	1.4045
6	LN BRINE FROM STG 4		45.77									6.40	18.57	12.17	2.70	450.88	1.3782
7	RCLAIM BRINE-TOTAL		592.18									3.90	3.78	-0.12	2.70	4.49	1.2623
8	RECLM BR TO 2ND BAR		155.67				1567.69	821.71	745.98	140.50	530.95		0.20				1.2362
9	RECLM BR TO 3RD BAR		104.39				414.11	216.10	198.01	140.50	140.93		0.20				1.2362
10	RECYCLE BRINE		35.94				451.00	255.00	195.20	140.50	138.93		0.20				1.2362
11	FEED TO 1ST BARO		68.87									3.90	4.07	0.17	2.70	6.32	1.2651
12	FEED TO DISSOLVERS		00.93										21.23				1.3972
13	FEED TO HOT TANK		00.93									4.20	12.56	8.36	2.70	309.59	1.3251
14	FEED TO STG 1		77.55										0.16				1.2392
15	SLURRY TO STG 2		18.53				252.17	116.50	133.67	28.18	474.28		0.16				1.2388
16	SLURRY TO STG 3		13.01				56.62	-30.75	95.37	9.99	954.48	9.70	8.67	-1.03	2.70	38.08	1.3016
17	SLURRY TO STG 4		12.66				47.93	-28.27	76.20	10.65	715.61	27.40	26.04	-1.36	2.70	50.42	1.4284
18	PRODUCT SLURRY		17.69				45.94	22.22	23.71	10.20	232.44	17.00	19.95	2.95	2.60	113.41	1.3837
19	DISCARD BRINE		9.04				84.47	35.48	48.99	9.17	534.53	31.50	59.69	28.19	2.70	1044.24	1.6559
20	RECLM BR TO 4TH BAR		252.13									3.90	3.95	0.05	2.70	1.78	1.2617
21	DISCH BR 2ND BAR		161.74				702.50	349.74	352.77	281.00	125.54		0.20				1.2362
22	DISCH BR 3RD BAR		100.23										0.20				1.2365
23	DISCH BR 4TH BAR		206.76										0.20				1.2383
24	RETURN BRINE		598.74										0.20				1.2360
25	STG 1 QUENCH WATER	1.00	1.00	0.00	1.20	0.01							0.20				1.2368
26	STG 2 QUENCH WATER	1.20	1.20	-0.00	0.60	0.02											
27	STG 3 QUENCH WATER	0.46	0.46	-0.00	0.23	0.01											
28	STG 4 QUENCH WATER	1.00	1.00	-0.00	0.66	0.03											
29	STG 1 VAPOR		12.06														
30	STG 2 VAPOR		6.07										0.00				0.0000
31	STG 3 VAPOR		4.16										0.00				0.0000
32	STG 4 VAPOR		4.64										0.00				0.0000
33	WATER TO DUST MIX	17.98	17.98	0.00	4.80	0.01							0.00				0.0000
34	STEAM TO DISSOLVERS	19.98	19.98	0.00	0.06	0.08											
35	STEAM CARRYOVER	0.60	0.60	-0.00	6.00	0.00											
36	CONDENSATE		19.38														
37	FINAL CONDENSATE	19.98	19.98	-0.00	0.06	0.11							0.00				0.0000
38	WATER IN FLOCC	1.20	1.20	0.00	0.24	0.50											

KILBORN(SASKATCHEWAN) LTD.

POTASH CRYSTALLISER SIMULATION
ANALYSIS TABLE

	SOLIDS NACL	SOLIDS KCL	SOLIDS MGCL2	SOLIDS	BRINE NACL	BRINE KCL	BRINE MGCL2	BRINE H2O	BRINE	S.G.
NEW MATERIAL	32.14	64.60	0.00	96.74	-10.96	0.35	0.00	13.87	3.26	1.9760
HOT BRINE U/F	0.06	7.37	0.00	7.43	12.61	10.52	0.00	69.44	93.57	1.2891
MEAS	0.06	5.74	0.00	5.80	12.44	10.56	0.00	71.20	94.20	1.2760
RESID	0.00	1.63	0.00	1.63	0.17	-0.04	0.00	-1.76	-1.63	0.0132
STAT	0.04	2.67	0.00	2.70	0.50	0.14	0.00	2.75	2.70	0.0203
RATIO X	4.87	69.09	0.00	60.46	33.73	26.66	0.00	64.09	60.46	64.99
LEAN BRINE TO BIG 2	0.09	13.53	0.00	13.62	16.43	16.39	0.00	53.56	86.38	1.3434
MEAS	0.09	9.61	0.00	9.70	15.51	16.39	0.00	58.40	90.30	1.3103
RESID	0.00	3.92	0.00	3.92	0.92	-0.00	0.00	-4.84	-3.92	0.0330
STAT	0.04	2.68	0.00	2.70	0.50	0.14	0.00	2.75	2.70	0.0201
RATIO X	12.00	146.43	0.00	145.27	184.09	0.87	0.00	176.07	145.27	163.98
LEAN BRINE TO BIG 3	0.05	21.70	0.00	21.76	16.62	12.16	0.00	49.46	78.24	1.4045
MEAS	0.05	15.35	0.00	15.40	15.05	12.25	0.00	57.30	84.60	1.3501
RESID	0.01	6.35	0.00	6.36	1.56	-0.09	0.00	-7.84	-6.36	0.0544
STAT	0.03	2.69	0.00	2.70	0.50	0.14	0.00	2.75	2.70	0.0202
RATIO X	25.75	235.83	0.00	235.49	312.68	63.10	0.00	284.93	235.49	268.70
LEAN BRINE TO BIG 4	0.04	18.54	0.00	18.57	17.37	13.30	0.00	50.76	81.43	1.3782
MEAS	0.04	6.36	0.00	6.40	17.16	13.04	0.00	63.40	93.60	1.2801
RESID	-0.00	12.17	0.00	12.17	0.21	0.26	0.00	-12.64	-12.17	0.0981
STAT	0.02	2.68	0.00	2.70	0.50	0.15	0.00	2.75	2.70	0.0203
RATIO X	4.87	453.56	0.00	450.88	41.41	170.27	0.00	459.51	450.88	483.00
LN BRINE FROM BIG 4	0.01	3.77	0.00	3.78	19.18	11.24	0.00	65.81	96.22	1.2623
MEAS	0.01	3.89	0.00	3.90	18.29	11.41	0.00	66.40	96.10	1.2607
RESID	0.00	0.12	0.00	-0.12	0.89	-0.18	0.00	-0.59	0.12	0.0015
STAT	0.01	0.11	0.00	2.70	0.50	0.16	0.00	0.54	2.70	0.0203
RATIO X	2.14	108.72	0.00	4.49	178.11	113.14	0.00	110.75	4.49	7.60
RCLAIM BRINE-TOTAL	0.10	0.10	0.00	0.20	21.40	6.70	0.00	71.70	99.80	1.2362
MEAS	0.10	0.10	0.00	0.20	21.40	6.70	0.00	71.70	99.80	1.2362
RESID	-0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.0000
STAT	0.05	0.05	0.00	0.00	0.50	0.50	0.00	0.71	0.00	0.0000
RATIO X	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	1.53	0.00
RECLM BR TO 2ND BAR	0.10	0.10	0.00	0.20	21.40	6.70	0.00	71.70	99.80	1.2362
MEAS	0.10	0.10	0.00	0.20	21.40	6.70	0.00	71.70	99.80	1.2362
RESID	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.0000
STAT	0.05	0.05	0.00	0.00	0.50	0.50	0.00	0.71	0.00	0.0000
RATIO X	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
RECLM BR TO 3RD BAR	0.10	0.10	0.00	0.20	21.40	6.70	0.00	71.70	99.80	1.2362
MEAS	0.10	0.10	0.00	0.20	21.40	6.70	0.00	71.70	99.80	1.2362
RESID	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.0000
STAT	0.05	0.05	0.00	0.00	0.50	0.50	0.00	0.71	0.00	0.0000
RATIO X	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00

NIPIGON GOSSAN TIMBER LTD. POTASH CRYSTALLISER SIMULATION

ANALYSIS TABLE

	SOLIDS				BRINE					
	NACL	KCL	MGCL2	SOLIDS	NACL	KCL	MGCL2	H2O	BRINE	S.G.
RECYCLE BRINE	0.01	4.06	0.00	4.07	19.34	10.89	0.00	65.70	95.93	1.2651
MEAS	0.01	3.89	0.00	3.90	18.29	11.41	0.00	66.40	96.10	1.2667
RESID	0.00	0.17	0.00	0.17	1.05	-0.53	0.00	-0.70	-0.17	0.0044
STAT	0.01	0.11	0.00	2.70	0.50	0.16	0.00	0.54	2.70	0.0203
RATIO %	12.43	191.96	0.00	6.32	210.35	334.03	0.00	131.17	6.32	21.42
FEED TO 1ST BOIL	0.10	21.13	0.00	21.23	14.91	10.19	0.00	51.67	78.77	1.3173
FEED TO DISSOLVERS	0.09	12.46	0.00	12.56	15.31	15.89	0.00	56.25	87.44	1.3251
MEAS	0.10	4.10	0.00	4.20	16.40	16.20	0.00	63.20	95.80	1.2611
RESID	0.01	8.36	0.00	8.36	-1.09	-0.31	0.00	-6.95	-8.36	0.0640
STAT	0.05	2.70	0.00	2.70	0.50	0.24	0.00	2.76	2.70	0.0204
RATIO %	10.83	309.79	0.00	309.59	218.59	130.06	0.00	252.10	309.59	314.12
FEED TO HOT TANK	0.07	0.09	0.00	0.16	15.34	20.26	0.00	56.35	99.84	1.2392
MEAS	0.10	0.10	0.00	0.20	16.00	20.60	0.00	63.20	99.80	1.2411
RESID	0.03	-0.01	0.00	-0.04	-0.66	7.66	0.00	-6.95	0.04	-0.0018
STAT	0.05	0.05	0.00	2.70	0.50	0.50	0.00	0.71	2.70	0.0201
RATIO %	68.51	13.90	0.00	1.53	132.14	1523.96	0.00	973.56	1.53	9.18
FEED TO STG 1	0.06	0.10	0.00	0.16	15.41	20.85	0.00	55.58	99.84	1.2388
MEAS	0.10	0.10	0.00	0.20	15.70	19.10	0.00	65.00	99.80	1.2398
RESID	-0.04	0.00	0.00	-0.04	-0.29	9.75	0.00	-9.42	0.04	-0.0010
STAT	0.05	0.05	0.00	0.00	0.50	0.50	0.00	0.71	0.00	0.0000
RATIO %	72.65	7.30	0.00	3997.54	57.41	1939.48	0.00	1318.68	3997.80	13147.19
SLURRY TO STG 2	0.11	8.56	0.00	8.67	15.24	16.42	0.00	59.67	91.33	1.3016
MEAS	0.12	9.58	0.00	9.70	15.48	16.42	0.00	58.40	90.30	1.3103
RESID	-0.00	-1.03	0.00	-1.03	-0.24	0.00	0.00	1.27	1.03	-0.0087
STAT	0.04	2.67	0.00	2.70	0.50	0.14	0.00	2.75	2.70	0.0201
RATIO %	3.07	38.48	0.00	38.08	48.53	0.23	0.00	46.21	38.08	43.08
SLURRY TO STG 3	0.16	25.88	0.00	26.04	12.60	10.48	0.00	50.88	73.96	1.4204
MEAS	0.16	27.24	0.00	27.40	12.94	10.46	0.00	49.20	72.60	1.4401
RESID	-0.01	-1.36	0.00	-1.36	-0.34	0.01	0.00	1.68	1.36	-0.0117
STAT	0.06	2.68	0.00	2.70	0.50	0.12	0.00	2.75	2.70	0.0202
RATIO %	9.92	50.50	0.00	50.43	67.15	11.62	0.00	61.24	50.43	57.77
SLURRY TO STG 4	0.03	19.92	0.00	19.95	15.32	11.59	0.00	53.14	80.05	1.3837
MEAS	0.03	16.97	0.00	17.00	15.27	11.53	0.00	56.20	83.00	1.3599
RESID	-0.00	2.95	0.00	2.95	0.05	0.05	0.00	-3.06	-2.95	0.0238
STAT	0.03	2.60	0.00	2.60	0.50	0.13	0.00	2.65	2.60	0.0195
RATIO %	2.10	113.64	0.00	113.41	10.73	39.12	0.00	115.22	113.41	121.69
PRODUCT SLURRY	0.27	59.42	0.00	59.69	14.13	8.10	0.00	18.08	40.31	1.6559
MEAS	0.22	31.28	0.00	31.50	12.98	8.32	0.00	47.20	68.50	1.4683
RESID	0.05	28.14	0.00	28.19	1.15	-0.22	0.00	-29.12	-28.19	0.1876
STAT	0.07	2.68	0.00	2.70	0.50	0.11	0.00	2.75	2.70	0.0203
RATIO %	77.96	1049.23	0.00	1044.24	229.81	197.55	0.00	1059.60	1044.24	922.80

KILBORN(SASKATCHEWAN) LTD.

POTASH CRYSTALLISER SIMULATION
ANALYSIS TABLE

	SOLIDS				BRINE					
	NACL	KCL	MGCL2	SOLIDS	NACL	KCL	MGCL2	H2O	BRINE	S.G.
DISCARD BRINE	0.11	3.84	0.00	3.95	18.49	11.36	0.00	66.21	96.05	1.2617
MEAS	0.10	3.80	0.00	3.90	18.20	11.50	0.00	66.40	96.10	1.2605
RESID	0.01	0.04	0.00	0.05	0.29	-0.14	0.00	-0.19	-0.05	0.0013
STAT	0.05	0.10	0.00	2.70	0.50	0.16	0.00	0.54	2.70	0.0203
RATIO %	21.79	37.23	0.00	1.78	57.58	91.44	0.00	36.16	1.78	5.94
RECLM BR TO 4TH BAR	0.10	0.10	0.00	0.20	21.40	6.70	0.00	71.70	99.80	1.2362
MEAS	0.10	0.10	0.00	0.20	21.40	6.70	0.00	71.70	99.80	1.2362
RESID	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.0000
STAT	0.05	0.05	0.00	0.00	0.50	0.50	0.00	0.71	0.00	0.0000
RATIO %	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
DISCH BR 2ND BAR	0.10	0.10	0.00	0.20	20.81	6.51	0.00	72.47	99.80	1.2365
DISCH BR 3RD BAR	0.10	0.10	0.00	0.20	21.76	6.81	0.00	71.23	99.80	1.2383
DISCH BR 4TH BAR	0.10	0.10	0.00	0.20	21.12	6.61	0.00	72.07	99.80	1.2360
RETURN BRINE	0.10	0.10	0.00	0.20	21.23	6.65	0.00	71.92	99.80	1.2368

APPENDIX B

APPENDIX B

DESCRIPTION OF THE MASS ENTHALPY BALANCING SOFTWARE

The mass/enthalpy balancing system is described by the acronym COMEBAL which means, Coherent Mass Enthalpy Balancing . It consists of 26 components which are listed below:

COMEBAL	Main Program
BOTM	Thermodynamic Balancing System
CALCFX	Control Subroutine for BOTM
CONV	Convert Analysis Data Program
BC	Brine Condition Subroutine
DIL	Determine Dilution Function
VOL	Compute Volumetric Flows
CALCFY	Water Balance Control Routine
WTBAL	Solve Water Balance
J3MAT	Setup Analysis Balance
ANBAL	Solve Analysis Balance
COGGIN	Implement COGGINS Algorithm
ANTAB	Print Analysis Balance
TEMPTT	Print Temperature Profile
FLOWTB	Print Flow Results
RB	Compute Brine Specific Gravity
ENTH	Calculate Stream Enthalpies
RW	Compute Water Specific Gravity
X1	Compute NaCl Joint Saturation
X2	Compute KCl Joint Saturation
Z1	Compute NaCl Saturation (KCL Undersaturated)
Z2	Compute KCl Saturation (NaCl Undersaturated)
DX1	Partial Derivative of X1 Re Temperature
DX2	Partial Drivative of X2 Re Temperature
DZ1	Partial Derivative of Z1 Re Temperature
DZ2	Partial Derivative of Z2 Re Temperature

The system also contains a number of subroutines for matrix manipulation and the solution of sets of linear homogeneous equations as well as the determination of rank and matrix structure.

COMEBAL

The main control program accepts data which describe the circuit topology and the measurement set. It then accepts each measurement and the statistical error on that measurement in the general format

$$x \quad \sigma_x$$

first for temperature, then flow and density then analysis.

A large part of the system logic consists of an elaborate error model that enables the system to derive the set $D_{aj}^{\rho}, D_{aj}^{w}, \delta_{aj}, a_{mj}$ and their statistics.

Built into this error model is a means of performing such arithmetic as

Pulp Flow = specific gravity * volumetric flow rate

$$D^{\rho} = \rho V$$

the system would calculate σ^{ρ} as a function of the σ^{ρ} and σ^{v} that are supplied as input data.

On the basis of temperature alone the system will attempt to develop as much as it can the estimates of measured variables and their statistics. As the data input system moves up the input data heirarchy (i.e. flow, density, analysis) and depending upon the statistical variations of flow, density and analysis the system will build a data base of values

$$D_{oj}^{\rho} \quad \sigma_j^{\rho}$$

$$\delta_{oj} \quad \sigma_j^{\delta}$$

$$D_{oj}^{w} \quad \sigma_j^{w}$$

$$a_{mj} \quad \sigma_{mj}$$

to the fullest extent of the capabilities of the error model and the input data.

It should be noted that the system must construct a starter solution to initiate the numerical processing. As a coherent balance evolves the incorrect assumptions that are made at the start of the process are corrected.

BOTM

This program was supplied to Kilborn by Dr. Laguitton of EMR[3]. Its function is to perform the overall J minimization which determines ultimate values of D_v, and T_j for each stream.

The methodology of the program is the implementation of the method of conjugate directions due to POWELL.

CALCFX

This is a control routine called by BOTM which updates the work of COMEBAL as coherency in the solution improves.

CONV

This subroutine accepts total NaCl and total KCl measurements plus percent solids in order to derive a_{mj} and σ_{mj} for each stream where there is analysis.

BC

This subroutine will calculate a_{mj} and σ_{mj} even if only temperature is known.

The routine provides the means whereby the solution chemistry constraint is reintroduced as a statistical constraint. The procedure involves the introduction of the concept known as brine condition which has the values.

Brine Condition	Comment
1	Saturation KCl and NaCl
2	Saturation KCl
3	Saturation NaCl
4	Saturation KCl and NaCl (clear)
5	Saturation KCL (clear)
6	Saturation NaCl (clear)
7	Undersaturated
8	Water

DIL

This routine determines δ_{oj} and σ_j^{δ} given the density and/or the composition of the stream. Dilution, because of the form

$$\delta_j = D_j^w / D_j$$

produces a quadratic (in D^w) measure of density which is essential to the water balancing procedure.

VOL

This routine determines D_{oj}^{w} and/or D_{oj}^{s} when flow and/or density measurements are supplied. It also computes D_{oj}^{w} values for vapor and steam flows.

CALCFY

This subroutine computes the matrix U, and the vector W and the scalar T. It calls the water balance routine then computes the feed/water functional J_{12}. CALCFY runs under control of the COGGIN routine for optimizing the feed solids D_1.

WTBAL

This subroutine computes the water balance $\hat{D}^w$ according to equation (15). In effect this provides a J_{12} minimization based upon the method of Lagrangian multipliers.

J3MAT

This subroutine constructs the analysis balance in the following matrix form

$$\min_{z} J_3 = (z-a)^T V^{-1}(z-a)$$

subject to

$$Cz = e$$

Included in C are the enthalpy and species conservation equations. Also included are slack variables relating to dissolver condensate and steam that carries over from the exchanger to the condensate trap. This assures that there will be an energy balance between the dissolvers and the crystallizers.

ANBAL

This is a subroutine to solve the problem created by J3MAT. The method paralles that of WTBAL with the difference being problem size. The ANBAL problem for CCP consists of 42 equations in 193 variables. Arithmetic precision is seven decimal digits and the psuedo-rank of the matrix is less than full. However, the computation goes to completion with a solution error on the enthalpy balance which is of no physical significance. This is caused by roundoff and/or truncation error.

COGGIN

This is a routine for minimizing a nonlinear single variable function. It is used in the J_{12} minimization to determine D_1.

ANTAB TEMPTT AND FLOWTB

These routines print the results in the form of three tableaux illustrating analysis, temperature and flow profiles.

RB

This subroutine calculates brine specific gravity as a function of temperature and saturation level.

RW

This subroutine calculates the specific gravity of air saturated water and a function of temperature.

ENTH

The specific enthalpy of each component of a stream is calculated by this routine. It allows for enthalpy of solution and can determine the enthalpy of water, saturated and superheated steam. A separate routine can calculate vapor pressure or boiling point rise within a crystallizer unit.

X1, X2, Z1 AND Z2

These functions determine joint and separate saturation functions with respect to temperature and the level of undersaturation of the undersaturated component.

Taken as a group these functions completely describe the $NaCl-KCl-H_2O$ phase diagram. The partial derivatives re temperature are given by DX1, DX2, DZ1 and DZ2.

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:22                              PAGE:    1

REQUESTED OPTIONS (EXECUTE): NODECK,SOURCE,NOLIST,OPT(3)

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(3)  LANGLVL(77) NOEPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                *....*...1.........2.........3.........4.........5.........6.........7.*.......8
                C
                C  THIS IS COHEBAL(COHERENT MASS ENTHALPY BALANCING FOR POTASH CIRCUITS)  00000010
                C                                                                        00000020
ISN         1       COMMON NL,NQ1,NQ2,NQ3,NP1,NP2,NP3,MMAX                               00000030
ISN         2       COMMON NTYPE(20),NSTYP(50),NBC(50),F(50),R(50),SF(50),SR(50),        00000040
                   1      NODE(20),DSCND(20,10),NSTR(50),DSCST(10,50),AM1(20,50),       00000050
                   2       T(50),P(50),ST(50),SP(50),ZD(3,50),SZ(3,50),NRF(50),         00000060
                   3       NTP(50),NZ(50),A(350),V(350),Z(350),ZM(7),SZM(7),D(50),      00000070
                   4       DP(50),DW(50),DDW(50),DD(50),SDP(50),SW(50),SDD(50),         00000080
                   5       U(1000),W(50),H(350),C(9999),E(110),TH(100),ED(50),HT(7)     00000090
                   6      ,EED,NT(50),EPS,NNT,ZS(50),SI(50),NZS(50)                     00000100
ISN         3       DIMENSION SDK(50),ZDK(100)                                         00000110
ISN         4       NI=5                                                               00000120
ISN         5       NO=6                                                               00000130
ISN         6       EED=1.0E+2                                                         00000140
ISN         7       EPS=1.0E-4                                                         00000150
ISN         8       READ(NI,*) NQ1,NP1,NQ2,NP2,NQ3,NP3,MMAX                            00000160
ISN         9       NL=2*MMAX+1                                                        00000170
ISN        10       NN=NL*NP1                                                          00000180
ISN        11       CALL DINIT(D,NP1,0)                                                00000190
ISN        12       CALL DINIT(A,NN,0)                                                 00000200
ISN        13       E2=EED*EED                                                         00000210
                C                                                                     00000220
                C-INITIALIZE REQD ARRAYS                                              00000230
                C                                                                     00000240
ISN        14       CALL NINIT(NTP,NP1,0)                                              00000250
ISN        15       CALL NINIT(NZS,NP1,0)                                              00000260
ISN        16       CALL NINIT(NRF,NP1,0)                                              00000270
ISN        17       CALL NINIT(NZ,NP1,0)                                               00000280
ISN        18       CALL DINIT(V,NN,E2)                                                00000290
ISN        19       CALL DINIT(P,NP1,0)                                                00000300
ISN        20       CALL DINIT(SP,NP1,EED)                                             00000310
ISN        21       CALL DINIT(DP,NP1,0)                                               00000320
ISN        22       CALL DINIT(DDW,NP1,0)                                              00000330
ISN        23       CALL DINIT(DD,NP1,0)                                               00000340
ISN        24       CALL DINIT(SDP,NP1,EED)                                            00000350
ISN        25       CALL DINIT(SW,NP1,EED)                                             00000360
ISN        26       CALL DINIT(SDD,NP1,EED)                                            00000370
                C                                                                     00000380
                C READ NETWORK TOPOLOGY                                               00000390
                C                                                                     00000400
ISN        27       DO 1 I=1,NQ1                                                       00000410
ISN        28       READ(NI,102) NODE(I),NTYPE(I),(DSCND(I,J),J=1,10)                  00000420
ISN        29     102 FORMAT(2I3,10A2)                                                 00000430
ISN        30       1 CONTINUE                                                         00000440
ISN        31       DO 3 J=1,NP1                                                       00000450
ISN        32       3 READ(NI,104) NSTR(J),NSTYP(J),NBC(J),(DSCST(I,J),I=1,10)         00000460
ISN        33     104 FORMAT(3I3,10A2)                                                 00000470
ISN        34       DO 5 I=1,NQ1                                                       00000480
ISN        35       DO 5 J=1,NP1                                                       00000490
ISN        36       5 AM1(I,J)=0                                                       00000500
                                                                                      00000510
```

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                *....*...1.....2.....3.....4.....5.....6.....7.*.....8
ISN       37        8 READ(NI,*) I,J,ZZ                                  00000520
ISN       38          NNZ=ZZ                                             00000530
ISN       39          IF(NNZ)6,7,6                                       00000540
ISN       40        6 AM1(I,J)=NNZ                                       00000550
ISN       41          GO TO 8                                            00000560
                C                                                        00000570
                C ANALYSE INCIDENT MATRIX STRUCTURE                      00000580
                C                                                        00000590
ISN       42        7 NQ=NQ2-1                                           00000600
ISN       43          DO 9 I=1,NQ                                        00000610
ISN       44          NP=NP2-NQ2+I+1                                     00000620
ISN       45          DO 10 J=NP,NP2                                     00000630
ISN       46          IF(AM1(I,J).NE.0) GO TO 11                         00000640
ISN       47       10 CONTINUE                                           00000650
ISN       48          IF(AM1(I,NP-1).EQ.0) GO TO 12                      00000660
ISN       49        9 CONTINUE                                           00000670
ISN       50          IF(AM1(NQ2,NP2).NE.0) GO TO 13                     00000680
ISN       51       12 WRITE(NO,116) I                                    00000690
ISN       52      116 FORMAT(' ZERO DIAGONAL POSITION ',I3)              00000700
ISN       53          STOP                                               00000710
ISN       54       11 WRITE(NO,115) I,J                                  00000720
ISN       55      115 FORMAT(' NON ZERO UPPER DIAG ELEMENT ROW ',I3,' COL ',I3) 00000730
ISN       56          STOP                                               00000740
                C                                                        00000750
                C  READ TEMPERATURE AND PRESSURE DATA                    00000760
                C                                                        00000770
ISN       57       13 READ(NI,117) J,K,TI,STI,PI,SPI                     00000780
ISN       58          IF(K-1) 14,15,16                                   00000790
ISN       59      117 FORMAT(2I3,4F6.2)                                  00000800
ISN       60       15 T(J)=TI                                            00000810
ISN       61          ST(J)=STI                                          00000820
ISN       62          NTP(J)=K                                           00000830
ISN       63          GO TO 13                                           00000840
ISN       64       16 T(J)=TI                                            00000850
ISN       65          ST(J)=STI                                          00000860
ISN       66          P(J)=PI                                            00000870
ISN       67          SP(J)=SPI                                          00000880
ISN       68          NTP(J)=K                                           00000890
ISN       69          GO TO 13                                           00000900
                C                                                        00000910
                C--READ DENSITY AND FLOW DATA                            00000920
                C                                                        00000930
ISN       70       14 READ(NI,117) J,K,DI,SDI,FI,SFI                     00000940
ISN       71          DI=.01*DI                                          00000950
ISN       72          SDI=.01*SDI                                        00000960
ISN       73          IF(K-1) 18,19,20                                   00000970
ISN       74       19 R(J)=DI                                            00000980
ISN       75          SR(J)=SDI                                          00000990
ISN       76          NRF(J)=K                                           00001000
ISN       77          GO TO 14                                           00001010
ISN       78       20 IF(K-2) 21,21,22                                   00001020
ISN       79       21 F(J)=FI                                            00001030
ISN       80          SF(J)=SFI                                          00001040
ISN       81          NRF(J)=K                                           00001050
ISN       82          GO TO 14                                           00001060
ISN       83       22 R(J)=DI                                            00001070
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                *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN      84          SR(J)=SDI                                              00001080
ISN      85          E(J)=EI                                                00001090
ISN      86          SF(J)=SFI                                              00001100
ISN      87          NRF(J)=K                                               00001110
ISN      88          GO TO 14                                               00001120
                C                                                          00001130
                C  READ ANALYSIS INFORMATION -- MACL, KCL, % SOLIDS        00001140
                C                                                          00001150
ISN      89       18 READ(NI,123) J,(ZDK(K),K=1,3),(GDK(K),K=1,3)          00001160
ISN      90      123 FORMAT(I3,6F6.2)                                       00001170
ISN      91          IF(J.EQ.0) GO TO 24                                    00001180
ISN      92          DO 25 K=1,3                                            00001190
ISN      93          SZ(K,J)=.01*SDK(K)                                     00001200
ISN      94       25 ZD(K,J)=.01*ZDK(K)                                     00001210
ISN      95          NZ(J)=1                                                00001220
ISN      96          GO TO 18                                               00001230
                C                                                          00001240
                C  COMPUTE ANALYSIS A AND STATISTIC V MATRICES FOR THE J3 PROBLEM  00001250
                C  SET INITIALIZATION FLAG FOR 1ST ITERATION               00001260
                C                                                          00001270
ISN      97       24 ISF=1                                                  00001280
ISN      98          DO 26 J=1,NF2                                          00001290
ISN      99          IF(NIP(J).EQ.0) GO TO 26                               00001300
ISN     100          DO 27 M=1,ML                                           00001310
ISN     101          CALL LOC(M,J,MJ,NL,NF2,0)                              00001320
ISN     102       27 ZM(M)=A(MJ)                                            00001330
                C                                                          00001340
                C  DETERMINE BRINE ANALYSIS WHERE POSSIBLE                 00001350
                C                                                          00001360
ISN     103          ZO=.001                                                00001370
ISN     104          CALL BC(J,ZM,NRC(J),ISF,T(J),ST(J),ZM,GZM,ZO,ZO,EE)    00001380
ISN     105          WRITE(NO,*) ZM,SZM                                     00001390
ISN     106          DO 28 M=1,ML                                           00001400
ISN     107          CALL LOC(M,J,MJ,NL,NF2,0)                              00001410
ISN     108          A(MJ)=ZM(M)                                            00001420
ISN     109       28 V(MJ)=SZM(M)**2                                        00001430
ISN     110       26 CONTINUE                                               00001440
                C                                                          00001450
                C  PICK UP STREAM ANALYSIS                                 00001460
                C                                                          00001470
ISN     111          DO 29 J=1,NF2                                          00001480
ISN     112          IF(NZ(J)) 29,29,30                                     00001490
ISN     113       30 CALL CONV(ZD(1,J),ZD(2,J),ZD(3,J),T(J),SZ(1,J),SZ(2,J),SZ(3,J),  00001500
                     1  ST(J),NRC(J),ZM,SZM)                               00001510
ISN     114          WRITE(NO,*) ZM,GZM                                     00001520
ISN     115          DO 35 M=1,ML                                           00001530
ISN     116          CALL LOC(M,J,MJ,NL,NF2,0)                              00001540
ISN     117          A(MJ)=ZM(M)                                            00001550
ISN     118       35 V(MJ)=SZM(M)**2                                        00001560
ISN     119       29 CONTINUE                                               00001570
                C                                                          00001580
                C  COMPUTE MUD FLOW, WATER FLOW, AND DILUTION DATA VECTORS 00001590
                C                                                          00001600
ISN     120          DO 31 J=1,NF1                                          00001610
ISN     121          IF(NRF(J).EQ.0) GO TO 31                               00001620
ISN     122          IF(NRF(J)-J) 32,33,32                                  00001630
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                *....*....1....+....2....+....3....+....4....+....5....+....6....+....7.*.....8
ISN      125        52 CALL LOC(4,J,J4,NL,NP2,0)                                          00001640
ISN      124           CALL LOC(4,J,J4,NL,NP2,0)                                          00001650
ISN      125           BZN=SQRT(V(J3))                                                    00001660
ISN      126           BZK=SQRT(V(J4))                                                    00001670
ISN      127           CALL DIR(R(J),T(J),A(J3),A(J4),BR(J),BT(J),BZN,BZK,NRC(J),DD(J),   00001680
                      1DDP(J))                                                           00001690
ISN      128           WRITE(N0,*) DD(J),DDP(J)                                           00001700
ISN      129           IF(NRC(J).EQ.31)33,33,34                                           00001710
ISN      130        34 CALL PURE(R(J),F(J),T(J),A(J3),BR(J),BF(J),HF(J),BHF(J))           00001720
ISN      131           WRITE(N0,*) H(J),BHF(J)                                            00001730
ISN      132           GO TO 31                                                           00001740
ISN      133        33 CALL VOR(F(J),T(J),BF(J),BT(J),INSTYP(J),HF(J),BHF(J),HAW(J),BW(J))00001750
ISN      134           WRITE(N0,*) HF(J),BHF(J),HAW(J),BW(J)                              00001760
ISN      135        31 CONTINUE                                                           00001770
                C                                                                        00001780
                C READ SOLIDS ACT FRACTIONS                                              00001790
                C TRANSFORM MEASUREMENTS AND STATISTICS                                  00001800
                C                                                                        00001810
ISN      136        50 READ (N1,52) J,ZSI,SSI                                             00001820
ISN      137           ZS(J)=ZSI                                                          00001830
ISN      138           SI(J)=SSI                                                          00001840
ISN      139           NZS(J)=1                                                           00001850
ISN      140           IF(J.EQ.0) GO TO 61                                                00001860
ISN      141           CALL LOC(1,J,J1,NL,NP2,0)                                          00001870
ISN      142           CALL LOC(2,J,J2,NL,NP2,0)                                          00001880
ISN      143           CALL LOC(3,J,J3,NL,NP2,0)                                          00001890
ISN      144           CALL LOC(4,J,J4,NL,NP2,0)                                          00001900
ISN      145           A1=A(J1)                                                           00001910
ISN      146           A2=A(J2)                                                           00001920
ISN      147           A3=A(J3)                                                           00001930
ISN      148           A4=A(J4)                                                           00001940
ISN      149           S=A1+A2                                                            00001950
ISN      150           A(J2)=ZSI*S                                                        00001960
ISN      151           A(J1)=(1.-ZSI)*S                                                   00001970
ISN      152           A(J3)=A1-A(J1)+A3                                                  00001980
ISN      153           A(J4)=A2-A(J2)+A4                                                  00001990
ISN      154           S1=SQRT(V(J1))                                                     00002000
ISN      155           S2=SQRT(V(J2))                                                     00002010
ISN      156           SS=SQRT((S1**2)+(S2**2))                                           00002020
ISN      157           V(J2)=((SSI*S)**2)+((ZSI*SS)**2)                                   00002030
ISN      158           V(J1)=((S0I*S)**2)+(((1.-ZSI)*SS)**2)                              00002040
ISN      159           GO TO 50                                                           00002050
ISN      160        51 CONTINUE                                                           00002060
ISN      161        52 FORMAT(I4,3F6.3)                                                   00002070
                C                                                                        00002080
                C  READ STARTER SOLUTION AND TOLERANCES                                  00002090
                C                                                                        00002100
ISN      162           NBAS=NP2-NL2                                                       00002110
ISN      163           READ(N1,*) (P(J),J=1,NBAS),(EP(J),J=1,NBAS)                        00002120
ISN      164           IPRINT=1                                                           00002130
ISN      165           ESCALE=2                                                           00002140
                C                                                                        00002150
                C EXECUTE POWELL ALGORITHM                                               00002160
                C                                                                        00002170
ISN      166           D1=P(1)                                                            00002180
ISN      167           DO 34 J=2,NBAS                                                     00002190
```

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                *....*....1....+....2....+....3....+....4....+....5....+....6....+....7.*....8
ISN      168          K=J-1                                                                  00002300
ISN      169          TH(K)=D(J)/D1                                                          00002310
ISN      170       36 ED(K)=ED(K)/D1                                                         00002320
ISN      171          NBAS1=NBAS-1                                                           00002330
                C                                                                           00002340
                C DETERMINE WATER IMBALANCE AT EACH QUERY STREAM                            00002350
                C                                                                           00002360
ISN      172          CALL CALCFX(NBAS1,TH,FJ,D1,1)                                          00002370
ISN      173          NNT=0                                                                  00002380
ISN      174          JJ=NBAS                                                                00002390
ISN      175          DO 40 J=1,NP2                                                          00002400
ISN      176          W(J)=1                                                                 00002410
ISN      177          DO 41 M=1,M                                                            00002420
ISN      178          CALL LOC(M,J,MJ,ML,MEJ,0)                                              00002430
ISN      179       41 W(J)=W(J)-Z(MJ)                                                        00002440
ISN      180          NT(J)=0                                                                00002450
ISN      181          IF(ABS(W(J)).GE.EPS1 THEN                                              00002460
ISN      182          NT(J)=JJ                                                               00002470
ISN      183          NNT=NNT+1                                                              00002480
ISN      184          TH(JJ)=T(J)                                                            00002490
ISN      185          ED(JJ)=ST(J)                                                           00002500
ISN      186          JJ=JJ+1                                                                00002510
ISN      187          NBAS1=NBAS1+1                                                          00002520
ISN      188          END IF                                                                 00002530
ISN      189       40 CONTINUE                                                               00002540
ISN      190          CALL ENBAL(NO1,NP1,H,Z,D,DW)                                           00002550
ISN      191          CALL TEMPFT                                                            00002560
ISN      192          CALL ANTAB                                                             00002570
ISN      193          CALL FLOTAB                                                            00002580
                C  87 DO 88 J=1,NP2                                                         00002590
                C     CALL LOC (ML,J,JL,NL,NP2,0)                                           00002600
                C  88 D(J)=(D(J)+DW(J))*(1-Z(JL))                                           00002610
                C     D1=D(1)                                                               00002620
                C     DO 89 J=2,NBAS                                                        00002630
                C     K=J-1                                                                 00002640
                C  89 TH(K)=D(J)/D1                                                         00002650
                C     CALL CALCFX(NBAS1,TH,FJ,D1,0)                                         00002660
                C     CALL ENBAL(NO1,NP1,H,Z,D,DW)                                          00002670
                C     CALL TEMPFT                                                           00002680
                C     CALL ANTAB                                                            00002690
                C     CALL FLOTAB                                                           00002700
ISN      194          WRITE(NO,*) ((A(J),V(J)),J=1,NN)                                      00002710
ISN      195          WRITE(NO,*) ((DD(J),SDD(J),DF(J),SDF(J),DDW(J),SW(J)),J=1,NP1)        00002720
ISN      196          NW=NBAS1*(NBAS1+3)                                                    00002730
                C                                                                           00002740
                C BALANCE OF THERMODYNAMICS AND MASS - BOTH                                 00002750
                C                                                                           00002760
ISN      197       99 CALL BOTM(TH,ED,NBAS1,EF,ESCALE,IPRINT,05,ZIK,NT,NO,NW,D1)          00002770
ISN      198          WRITE(NO,95)                                                          00002780
ISN      199       95 FORMAT(1H1)                                                           00002790
ISN      200          WRITE(NO,*) (D(J),J=1,NP1)                                            00002800
ISN      201          WRITE(NO,*) (DW(J),J=1,NP1)                                           00002810
                C                                                                           00002820
                C FINAL RESULTS PRESENTATION                                                00002830
                C                                                                           00002840
ISN      202          DO 98 J=1,NP2                                                         00002850
```

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LEVEL 1.2.0 (SEPT 82)          OS FORTRAN          DATE 1983 DEC 27      TIME 12:58:22      NAME: MAIN    PAGE:    6

                ----*----1----------2----------3----------4----------5----------6----------7.--------8

ISN       203          DO 97 M=1,MM                                                          00002760
ISN       204          CALL LOC(M,J,MJ,ML,NE,2,0)                                            00002770
ISN       205       97 HT(M)=100*Z(MJ)                                                       00002780
ISN       206          WRITE(NO,96) (HT(K),K=1,ML)                                           00002790
ISN       207       96 FORMAT(5F10.3)                                                        00002800
ISN       208       98 CONTINUE                                                           00002810
ISN       209          CALL ENDAL(NO1,NF1,U,Z,D,IW)                                          00002820
ISN       210          CALL IENFFT                                                           00002830
ISN       211          CALL ANTAB                                                            00002840
ISN       212          CALL FLOTAB                                                           00002850
ISN       213          STOP                                                                  00002860
ISN       214       94 CONTINUE                                                           00002870
ISN       215          END                                                                   00002880

*STATISTICS*   SOURCE STATEMENTS = 215, PROGRAM SIZE = 9234 BYTES, PROGRAM NAME = MAIN     PAGE:    1.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 1 ******
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LEVEL 1.2.0 (SEPT 82)          OS/VS FORTRAN          DATE: 1983.006 22:27     TIME: 12:50:25      NAME: MAIN     PAGE:    7

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   OBJECT DECK   SOURCE   ITEM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1....+....2....+....3....+....4....+....5....+....6....+....7.*....+....8

                       C     ************************************************************************00000010
                       C BALANCE OF THERMODYNAMICS AND MASS                                          00000020
                       C                                                                             00000030
                       C MINIMIZATION OF  AN UNCONSTRAINED MULTIVARIABLE NONLINEAR                   00000040
                       C OBJECTIVE FUNCTION BY THE METHOD OF CONJUGATE DIRECTIONS                    00000050
                       C ...POWELL ALGORITHM                                                         00000060
                       C     ************************************************************************00000070
                       C-------------------------------------------------------------------------    00000080
                       C                                                                             00000090
ISN          1              SUBROUTINE NOTH (X,E,N,FF,ESCALE,IPRINT,MAXIT,W,NI,NO,NW,D1)          00000100
                       C                                                                             00000110
                       C          INTERMEDIATE VALUES OF THE OBJECTIVE FUNCTION AND                  00000120
                       C          INDEPENDENT VARIABLES ARE PRINTED OUT IN THIS SUBROUTINE.          00000130
                       C-------------------------------------------------------------------------    00000140
                       C                                                                             00000150
ISN          2              DIMENSION X(N), W(NW), E(N)                                           00000160
                       C                                                                             00000170
ISN          3              DNMAG=0.1*ESCALE                                                      00000180
ISN          4              SCER=0.05/ESCALE                                                      00000190
ISN          5              JJ=N*(N+1)                                                            00000200
ISN          6              JJJ=JJ+N                                                              00000210
ISN          7              K=N+1                                                                 00000220
ISN          8              NCC=1                                                                 00000230
ISN          9              IND=1                                                                 00000240
ISN         10              INN=1                                                                 00000250
ISN         11              DO 20 I=1,N                                                           00000260
ISN         12              W(I)=ESCALE                                                           00000270
ISN         13              DO 20 J=1,N                                                           00000280
ISN         14              W(K)=0.                                                               00000290
ISN         15              IF (I-J) 20,10,20                                                     00000300
ISN         16          10  W(K)=ABS(E(I))                                                       00000310
ISN         17          20  K=K+1                                                                00000320
ISN         18              ITERC=1                                                               00000330
ISN         19              ISUBAD=2                                                              00000340
                       C         ***************************************************************** 00000350
ISN         20              CALL CALCFX (N,X,F,D1,0)                                              00000360
                       C         ***************************************************************** 00000370
ISN         21              FKEEP=2.*ABS(F)                                                       00000380
ISN         22          30  ILINE=1                                                              00000390
ISN         23              FF=F                                                                  00000400
ISN         24              SUM=0.                                                                00000410
ISN         25              IXP=JJ                                                                00000420
ISN         26              DO 40 I=1,N                                                           00000430
ISN         27              IXP=IXP+1                                                             00000440
ISN         28          40  W(IXP)=X(I)                                                          00000450
ISN         29              IDIRN=N+1                                                             00000460
ISN         30              ILINE=1                                                               00000470
ISN         31          50  DMAX=W(ILINE)                                                         00000480
ISN         32              DACC=DMAX*SCER                                                        00000490
ISN         33              DMAG=AMIN1(DMAG,0.1*DMAX)                                             00000500
ISN         34              DMAG=AMAX1(DMAG,20.*DACC)                                             00000510
ISN         35              DMAX=10.*DMAG                                                         00000520
ISN         36              IF (ILINE.EQ.1) GO TO 200                                             00000530
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LEVEL 1.2 (SEPT 82)          OS/VS FORTRAN          DATE 1983 NOV 22     TIME 12:30:12          NAME: MAIN     PAGE:    8

                ----*----1----+----2----+----3----+----4----+----5----+----6----+----7-|--+----8
                C                                                                              00000540
ISN       37    60      DL=0.                                                                  00000550
ISN       38            D=DMAG                                                                 00000560
ISN       39            FIRST=1                                                                00000570
ISN       40            IB=5                                                                   00000580
ISN       41            FA=FIRST                                                               00000590
ISN       42            DA=DL                                                                  00000600
ISN       43    70      DB=D-DL                                                                00000610
ISN       44            DL=D                                                                   00000620
ISN       45    80      K=IDIRN                                                                00000630
ISN       46            DO 90 I=1,N                                                            00000640
ISN       47            X(I)=X(I)+DB*U(K)                                                      00000650
ISN       48    90      K=K+1                                                                  00000660
                C       ***************************************************************        00000670
ISN       49            CALL CALCFX (N,X,F,D1,0)                                               00000680
                C       ***************************************************************        00000690
ISN       50       900  NFCC=NFCC+1                                                           00000700
ISN       51            GO TO (300,270,250,230,100,540), IB                                    00000710
ISN       52    100     IF (F-FA) 140,110,150                                                  00000720
                C                                                                              00000730
ISN       53    110     IF  (ABS (D) DMAX) 120,120,130                                         00000740
ISN       54    120     D=D+D                                                                  00000750
ISN       55            GO TO 70                                                               00000760
ISN       56    130     WRITE (6,850)                                                          00000770
ISN       57            GO TO 830                                                              00000780
                C                                                                              00000790
ISN       58    140     FB=F                                                                   00000800
ISN       59            DB=D                                                                   00000810
ISN       60            GO TO 160                                                              00000820
ISN       61    150     FB=FA                                                                  00000830
ISN       62            DB=DA                                                                  00000840
ISN       63            FA=F                                                                   00000850
ISN       64            DA=D                                                                   00000860
ISN       65    160     IF (ISGRAD.EQ.1) GO TO 180                                             00000870
ISN       66    170     D=DB+DB-DA                                                             00000880
ISN       67            IB=1                                                                   00000890
ISN       68            GO TO 70                                                               00000900
ISN       69    180     D=0.5*(DA+DB-(FA-FB)/(DA-DB))                                          00000910
ISN       70            IB=4                                                                   00000920
ISN       71            IF ((DA-D)*(D-DB)) 190,70,70                                           00000930
ISN       72    190     IB=5                                                                   00000940
ISN       73            IF (ABS (D-DB)-DMAX) 70,70,200                                         00000950
ISN       74    200     D=DB+SIGN(DMAX,DB-DA)                                                  00000960
ISN       75            IB=1                                                                   00000970
ISN       76            DMAX=DMAX+DMAX                                                         00000980
ISN       77            DMAG=DMAG+DMAG                                                         00000990
ISN       78            IF(-(DMAG+0E-4.0E+40)-DMAG) 1.0E+40                                    00001000
ISN       80            IF (DMAX-DMAX) 70,70,210                                               00001010
ISN       81    210     DMAX=DMAX                                                              00001020
ISN       82            GO TO 70                                                               00001030
ISN       83    220     IF (F-FA) 230,170,170                                                  00001040
ISN       84    230     FC=FB                                                                  00001050
ISN       85            D=DB                                                                   00001060
ISN       86    240     FB=F                                                                   00001070
ISN       87            DB=D                                                                   00001080
ISN       88            GO TO 310                                                              00001090
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                *....*...1.....2.....3.....4.....5.....6.....7.*.....0

ISN      89   250   IF (F-FB) 230,230,260                                  00001100
ISN      90   260   FA=F                                                   00001110
ISN      91         DA=D                                                   00001120
ISN      92         GO TO 310                                              00001130
ISN      93   270   IF (F-FB) 280,300,300                                  00001140
ISN      94   280   FA=FB                                                  00001150
ISN      95         DA=DB                                                  00001160
ISN      96         GO TO 240                                              00001170
ISN      97   290   IL=1.                                                  00001180
ISN      98         IDMAX=5.                                               00001190
ISN      99         FA=FP                                                  00001200
ISN     100         DA=-1.                                                 00001210
ISN     101         FB=FMOD                                                00001220
ISN     102         DB=0.                                                  00001230
ISN     103         D=1.                                                   00001240
ISN     104   300   FC=F                                                   00001250
ISN     105         DC=D                                                   00001260
ISN     106   310   A=(DB-DC)*(FA-FC)                                      00001270
ISN     107         B=(DC-DA)*(FB-FC)                                      00001280
ISN     108         IF ((A+B)*(DA-DC)) 320,320,330                         00001290
ISN     109   320   FA=FB                                                  00001300
ISN     110         DA=DB                                                  00001310
ISN     111         FB=FC                                                  00001320
ISN     112         DB=DC                                                  00001330
ISN     113         GO TO 200                                              00001340
ISN     114   330   D=0.5*(A*(DB+DC)+B*(DA+DC))/(A+B)                      00001350
ISN     115         DI=DB                                                  00001360
ISN     116         FI=FB                                                  00001370
ISN     117         IF (FB-FC) 350,350,340                                 00001380
ISN     118   340   DI=DC                                                  00001390
ISN     119         FI=FC                                                  00001400
ISN     120   350   IF  (ITONE.NE.3) GO TO 370                            00001410
ISN     121   360   ITONE=2                                               00001420
ISN     122         GO TO 390                                              00001430
ISN     123   370   IF(ABS(D-DI)-DACC)430,430,380                          00001440
ISN     124   380   IF  (ABS (D-DI) 0.03*ABS (D)) 430,430,390              00001450
ISN     125   390   IF  ((DA-DC)*(DC-D)) 410,400,400                       00001460
ISN     126   400   FA=FB                                                  00001470
ISN     127         DA=DB                                                  00001480
ISN     128         FB=FC                                                  00001490
ISN     129         DB=DC                                                  00001500
ISN     130         GO TO 190                                              00001510
ISN     131   410   IB=2                                                   00001520
ISN     132         IF  ((DB-D)*(D-DC)) 420,70,70                          00001530
ISN     133   420   IB=3                                                   00001540
ISN     134         GO TO 70                                               00001550
ISN     135   430   F=FI                                                   00001560
ISN     136         D=DI-DL                                                00001570
ISN     137         DD=SQRT((DC-DD)*(DC-DA)*(DA-DD)/(A+B))                 00001580
ISN     138         DO 440 I=1,N                                           00001590
ISN     139         X(I)=X(I)+D*W(IDIRN)                                   00001600
ISN     140         W(IDIRN)=DD*W(IDIRN)                                   00001610
ISN     141   440   IDIRN=IDIRN+1                                          00001620
ISN     142         W(ILINE)=W(ILINE)/DD                                   00001630
ISN     143         ILINE=ILINE+1                                          00001640
ISN     144         IF (IPRINT-1) 460,450,460                              00001650
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                *....*...1.....2.....3.....4.....5.....6.....7.*.....0

                C                                                                00001660
 ISN      145   450    WRITE (IO,820) ITERC,NFCC,F,(X(I),I=1,N)                 00001670
 ISN      146          CALL TEMPFI                                              00001680
 ISN      147          CALL ANTAB                                               00001690
 ISN      148          CALL PLOTAB                                              00001700
 ISN      149          IF  (IDKIND.NE.1) GO TO 480                              00001710
 ISN      150   460    IF  (ITONE.NE.1) GO TO 660                               00001720
 ISN      151   470    IF  (FPREV-F 500) 490,480,480                            00001730
 ISN      152   480    SUM=FPREV-F                                              00001740
 ISN      153          JIL=ILINE                                                00001750
 ISN      154   490    IF  (IDIRN-JJ) 60,50,500                                 00001760
 ISN      155   500    IF  (IND.NE.1) GO TO 670                                 00001770
 ISN      156   510    FHOLD=F                                                  00001780
 ISN      157          IB=6                                                     00001790
 ISN      158          IXP=JJ                                                   00001800
 ISN      159          DO 520 I=1,N                                             00001810
 ISN      160          IXP=IXP+1                                                00001820
 ISN      161   520    W(IXP)=X(I)-W(IXP)                                       00001830
 ISN      162          DD=1.                                                    00001840
 ISN      163          GO TO 80                                                 00001850
 ISN      164   530    IF  (IND.NE.1) GO TO 560                                 00001860
 ISN      165   540    IF (FP-F) 630,630,550                                    00001870
 ISN      166   550    D=2.*(FP+F-2.*FHOLD)/(FP-F)**2                           00001880
 ISN      167          IF  (D*(FP-FHOLD-SUM)**2-SUM) 560,630,630                00001890
 ISN      168   560    J=JIL+N+1                                                00001900
 ISN      169          IF  (J-JJ) 570,570,600                                   00001910
 ISN      170   570    DO 580 I=J,JJ                                            00001920
 ISN      171          K=I-N                                                    00001930
 ISN      172   580    W(K)=W(I)                                                00001940
 ISN      173          DO 590 I=JIL,N                                           00001950
 ISN      174   590    W(I-1)=W(I)                                              00001960
 ISN      175   600    IDIRN=IDIRN-N                                            00001970
 ISN      176          ITONE=3                                                  00001980
 ISN      177          K=IDIRN                                                  00001990
 ISN      178          IXP=JJ                                                   00002000
 ISN      179          AAA=0.                                                   00002010
 ISN      180          DO 620 I=1,N                                             00002020
 ISN      181          IXP=IXP+1                                                00002030
 ISN      182          W(K)=W(IXP)                                              00002040
 ISN      183          IF  (AAA-ABS (W(K)/E(I))) 610,620,620                    00002050
 ISN      184   610    AAA=ABS(W(K)/E(I))                                       00002060
 ISN      185   620    K=K+1                                                    00002070
 ISN      186          DEMAG=1.                                                 00002080
 ISN      187          W(N)=ESCALE/AAA                                          00002090
 ISN      188          ILINE=N                                                  00002100
 ISN      189          GO TO 50                                                 00002110
 ISN      190   630    IXP=JJ                                                   00002120
 ISN      191          AAA=0.                                                   00002130
 ISN      192          F=FHOLD                                                  00002140
 ISN      193          DO 650 I=1,N                                             00002150
 ISN      194          IXP=IXP+1                                                00002160
 ISN      195          X(I)=X(I)-W(IXP)                                         00002170
 ISN      196          IF (AAA*ABS (F+E)+ABS (W(IXP))) 640,650,650              00002180
 ISN      197   640    AAA=ABS(W(IXP)/E(I))                                     00002190
 ISN      198   650    CONTINUE                                                 00002200
 ISN      199          GO TO 670                                                00002210
```

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                *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN      200   640    AAA=AAA*(1.+DI)                                        00002220
ISN      201          IF (IND.NE.1) GO TO 820                              00002230
ISN      202   670    IF (IPRINT-2) 680,650,680                            00002240
ISN      203   680    IF   (IND.NE.1) GO TO 720                            00002250
ISN      204   690    IF (AAA - 0.1) 830,830,700                           00002260
                C                                                          00002270
ISN      205   700    IF (F-FF) 730,710,710                                00002280
ISN      206   710    WRITE (NO,870)                                       00002290
ISN      207          GO TO 830                                            00002300
                C                                                          00002310
ISN      208   720    IND=1                                                00002320
ISN      209   730    DUMAG=0.4*SQRT(ABS(FF-F))                            00002330
ISN      210          IF   (DUMAG.GE.1.0E+60) DUMAG = 1.0E+60              00002340
ISN      212          ISQRAD=1                                             00002350
                C                                                          00002360
ISN      213          ITERC=ITERC+1                                        00002370
ISN      214          IF (ITERC-MAXIT) 30,30,740                           00002380
ISN      215   740    WRITE (NO,880) MAXIT                                 00002390
ISN      216          IF (F-FKEEP) 830,830,750                             00002400
ISN      217   750    F=FKEEP                                              00002410
ISN      218          DO 760 I=1,N                                         00002420
ISN      219          JJJ=JJJ+1                                            00002430
ISN      220   760    X(I)=W(JJJ)                                          00002440
ISN      221          GO TO 830                                            00002450
                C                                                          00002460
                C          CODE BETWEEN STARS IS NOT USED BUT WAS PART OF THE   00002470
                C          ORIGINAL VERSION OF THE PROGRAM                  00002480
                C          (SEE HARWELL LIBRARY ROUTINE VA04A)              00002490
                C                                                          00002500
                C     ********************************************************** 00002510
                C     JIL=1                                                00002520
                C     FF=FKEEP                                             00002530
                C     IF (F-FKEEP) 780,710,770                             00002540
                C 770 JIL=2                                                00002550
                C     FF=F                                                 00002560
                C     F=FKEEP                                              00002570
                C 780 IXP=JJ                                               00002580
                C     DO 810 I=1,N                                         00002590
                C     IXP=IXP+1                                            00002600
                C     K=IXP+N                                              00002610
                C     IF (JIL.EQ.1) 790,800                                00002620
                C 790 W(IXP)=W(K)                                          00002630
                C     GO TO 810                                            00002640
                C 800 W(IXP)=X(I)                                          00002650
                C     X(I)=W(K)                                            00002660
                C 810 CONTINUE                                             00002670
                C     JIL=2                                                00002680
                C     GO TO 510                                            00002690
                C     ********************************************************** 00002700
ISN      222   820    IF (AAA-0.1) 830,830,840                             00002710
ISN      223   830    EF=F                                                 00002720
ISN      224          RETURN                                               00002730
                C                                                          00002740
ISN      225   840    INN=1                                                00002750
ISN      226          GO TO 730                                            00002760
                C                                                          00002770
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                *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                C                                                              00002780
ISN      227    850    FORMAT (/,5X,30HMAXIMUM CHANGE DOES NOT ALTER FUNCTION) 00002790
ISN      228    860    FORMAT (/10H ITERATION,I5,11X,16H FUNCTION VALUES,10X,4HF =,E15.8/00002800
                     1 4(E16.8,2X))                                            00002810
ISN      229    870    FORMAT (/,5X,31HACCURACY LIMITED BY ERRORS IN F)         00002820
ISN      230    880    FORMAT (/,I5,29H ITERATIONS COMPLETED BY BOTH)           00002830
ISN      231           END                                                      00002840

*STATISTICS*   SOURCE STATEMENTS = 229, PROGRAM SIZE = 5590 BYTES, PROGRAM NAME = BOTH     PAGE:     7.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 2 ******
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OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   OBJSTM NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                       C                                                                    00000010
                       C CONTROL SUBROUTINE FOR OVERALL J MINIMIZATION                      00000020
                       C                                                                    00000030
                       C FUNCTIONS ARE:                                                     00000040
                       C ,DETERMINE NON BASIC VECTORS IN SOLIDS INCIDENT MATRIX             00000050
                       C , CHECK ABOVE FOR ILL CONDITIONING                                 00000060
                       C ,UPDATE MEASUREMENTS WHEN COHERENCE DEVELOPED                      00000070
                       C ,CONTROL J12 MINIMIZATION - COGGINS ALGORITHM                      00000080
                       C ,COMPUTE AND NORMALIZE ENTHALPY MATRIX                             00000090
                       C ,SET UP THERMODYNAMIC OPTIMIZATION                                 00000100
                       C                                                                    00000110
ISN        1               SUBROUTINE CALCFX(N,XI,FJ,D1,ISF)                               00000120
ISN        2               COMMON NL,NO1,NO2,NO3,NP1,NP2,NP3,MMAX                          00000130
ISN        3               COMMON NTYPE(20),NSIYR(50),NBC(50),F(50),R(50),SF(50),SR(50),   00000140
                          1       NODE(20),DSCND(20,10),NSTR(50),DSCST(10,50),AM1(20,50),  00000150
                          2       T(50),P(50),ST(50),SP(50),ZD(3,50),SZ(3,50),NRF(50),     00000160
                          3       NTP(50),NZ(50),A(350),V(350),Z(350),ZM(7),SZM(7),D(50),  00000170
                          4       DP(50),DW(50),DDW(50),DD(50),SDP(50),SW(50),SDD(50),     00000180
                          5       U(1000),W(50),H(350),C(9999),E(110),TH(100),ED(50),HT(7) 00000190
                          6       ,EED,NT(50),EPS,NNT,ZS(50),SI(50),NZS(50)                00000200
ISN        4               DIMENSION XI(1),AM2(1000),AM3(350),XX(20),DS(50)                00000210
ISN        5            99 NI=5                                                            00000220
ISN        6               NO=6                                                            00000230
ISN        7               IMAX=NL*NP2                                                     00000240
ISN        8               D(1)=D1                                                         00000250
ISN        9               NPP=NP2-NO2-1                                                   00000260
ISN       10               DO 50 J=1,NPP                                                   00000270
ISN       11            50 D(J+1)=D1*XI(J)                                                 00000280
ISN       12               DO 51 I=1,NO2                                                   00000290
ISN       13               NP=NP2-NO2                                                      00000300
ISN       14               DO 52 J=1,NP                                                    00000310
ISN       15               CALL LOC(I,J,IJ,NO2,NP,0)                                       00000320
ISN       16            52 AM2(IJ)=-AM1(I,J)                                               00000330
ISN       17               DO 53 J=1,NO2                                                   00000340
ISN       18               JJ=NP+J                                                         00000350
ISN       19               CALL LOC(I,J,IJ,NO2,NO2,0)                                      00000360
ISN       20            53 AM3(IJ)=AM1(I,JJ)                                               00000370
ISN       21            51 CONTINUE                                                        00000380
ISN       22               CALL MPRD(AM2,D,XX,NO2,NP,0,0,1)                                00000390
ISN       23               CALL GELG(XX,AM3,NO2,1,1.0E-4,IER)                              00000400
ISN       24               IF(IER) 54,55,54                                                00000410
ISN       25            54 WRITE(6,56)                                                     00000420
ISN       26            56 FORMAT(' CONDITIONING PROBLEMS - INCIDENT MATRIX')             00000430
ISN       27            55 DO 57 J=1,NO2                                                   00000440
ISN       28               JJ=J+NP                                                         00000450
ISN       29            57 D(JJ)=XX(J)                                                     00000460
ISN       30               WRITE (NO,*) (D(K),K=1,NP2)                                     00000470
ISN       31               WRITE(NO,*) (DW(K),K=1,NP1)                                     00000480
ISN       32               IF(ISF) 1,1,2                                                   00000490
ISN       33            1  DO 3 I=1,IMAX                                                   00000500
ISN       34            3  A(I)=Z(I)                                                      00000510
ISN       35               DO 26 J=1,NP2                                                   00000520
ISN       36               IC=I(J)                                                         00000530
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                *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN       37          IF(NT(J).NE.0) THEN                                    00000540
ISN       38          JJ=NT(J)                                               00000550
ISN       39          TC=XI(JJ)                                              00000560
ISN       40          END IF                                                 00000570
ISN       41          IF(NTP(J).EQ.0) GO TO 26                               00000580
ISN       42          DO 27 M=1,NL                                           00000590
ISN       43          CALL LOC(M,J,MJ,NL,NP2,0)                              00000600
ISN       44       27 ZM(M)=Z(MJ)                                            00000610
ISN       45          CALL BC(J,ZM,NBC(J),ISF,TC,ST(J),ZM,SZM,0,0,EED)       00000620
ISN       46          DO 28 M=1,NL                                           00000630
ISN       47          CALL LOC(M,J,MJ,NL,NP2,0)                              00000640
ISN       48          A(MJ)=ZM(M)                                            00000650
ISN       49       28 V(MJ)=SZM(M)**2                                        00000660
ISN       50       26 CONTINUE                                               00000670
ISN       51          DO 29 J=1,NP2                                          00000680
ISN       52          TC=T(J)                                                00000690
ISN       53          IF(NT(J).NE.0) THEN                                    00000700
ISN       54          JJ=NT(J)                                               00000710
ISN       55          TC=XI(JJ)                                              00000720
ISN       56          END IF                                                 00000730
ISN       57          IF(NZ(J)) 29,29,30                                     00000740
ISN       58       30 CALL CONV(ZD(1,J),ZD(2,J),ZD(3,J),TC,SZ(1,J),SZ(2,J),SZ(3,J),  00000750
                     1 ST(J),NBC(J),ZM,SZM)                                 00000760
ISN       59          DO 40 M=1,NL                                           00000770
ISN       60          CALL LOC(M,J,MJ,NL,NP2,0)                              00000780
ISN       61          A(MJ)=ZM(M)                                            00000790
ISN       62       40 V(MJ)=SZM(M)**2                                        00000800
ISN       63       29 CONTINUE                                               00000810
ISN       64          DO 59 J=1,NP2                                          00000811
ISN       65          IF(NZS(J).EQ.0) GO TO 59                               00000812
ISN       66          ZSI=ZS(J)                                              00000813
ISN       67          SSI=SI(J)                                              00000814
ISN       68          CALL LOC(1,J,J1,NL,NP2,0)                              00000815
ISN       69          CALL LOC(2,J,J2,NL,NP2,0)                              00000816
ISN       70          CALL LOC(3,J,J3,NL,NP2,0)                              00000817
ISN       71          CALL LOC(4,J,J4,NL,NP2,0)                              00000818
ISN       72          A1=A(J1)                                               00000819
ISN       73          A2=A(J2)                                               00000820
ISN       74          A3=A(J3)                                               00000821
ISN       75          A4=A(J4)                                               00000822
ISN       76          S=A1+A2                                                00000823
ISN       77          A(J2)=ZSI*S                                            00000824
ISN       78          A(J1)=(1-ZSI)*S                                        00000825
ISN       79          A(J3)=A1-A(J1)+A3                                      00000826
ISN       80          A(J4)=A2-A(J2)+A4                                      00000827
ISN       81          S1=SQRT(V(J1))                                         00000828
ISN       82          S2=SQRT(V(J2))                                         00000829
ISN       83          SS=SQRT((S1**2)+(S2**2))                               00000830
ISN       84          V(J2)=((SSI*S)**2)+((ZSI*SS)**2)                       00000831
ISN       85          V(J1)=((SSI*S)**2)+(((1-ZSI)*SS)**2)                   00000832
ISN       86       59 CONTINUE                                               00000834
                     C                                                      00000835
                     C--COMPUTE PULP FLOW, WATER FLOW AND DILUTION DATA VECTORS  00000836
                     C                                                      00000840
ISN       87          DO 4 J=1,NP1                                           00000850
ISN       88          DBW(J)=BW(J)                                           00000860
```

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                *....*...1.....2.....3.....4.....5.....6.....7.*.....8
ISN       89          IF(J.LE.NP2) THEN                                          00000870
ISN       90          DP(J)=D(J)+DW(J)                                           00000880
ISN       91          IF(D(J).NE.0) DD(J)=DW(J)/D(J)                             00000890
ISN       93          END IF                                                     00000900
ISN       94        4 CONTINUE                                                   00000910
ISN       95          DO 31 J=1,NP1                                              00000920
ISN       96          TC=T(J)                                                    00000930
ISN       97          IF(NT(J).NE.0) THEN                                        00000940
ISN       98          JJ=NT(J)                                                   00000950
ISN       99          TC=XI(JJ)                                                  00000960
ISN      100          END IF                                                     00000970
ISN      101          IF(NRF(J).EQ.0) GO TO 31                                   00000980
ISN      102          IF(NRF(J)-2) 32,33,32                                      00000990
ISN      103       32 CALL LOC(3,J,J3,NL,NP2,0)                                  00001000
ISN      104          CALL LOC(4,J,J4,NL,NP2,0)                                  00001010
ISN      105          SZN=SQRT(V(J3))                                            00001020
ISN      106          SZK=SQRT(V(J4))                                            00001030
ISN      107          CALL DIL(R(J),TC,A(J3),A(J4),SR(J),ST(J),SZN,SZK,NBC(J),DD(J),  00001040
                     1SDD(J))                                                   00001050
ISN      108          IF(NRF(J)-2) 31,33,34                                      00001060
ISN      109       34 CALL PULP(R(J),F(J),TC,A(J3),SR(J),SF(J),DP(J),SDP(J))     00001070
ISN      110          GO TO 31                                                   00001080
ISN      111       33 CALL VOL(F(J),TC,SF(J),ST(J),NBTYP(J),DP(J),SDP(J),DDW(J),SW(J))  00001090
ISN      112       31 CONTINUE                                                   00001100
ISN      113        2 XLIM=0.5                                                   00001125
ISN      114          XDEL=D1/10.                                              00001126
ISN      115          IPR=1                                                    00001130
ISN      116          DO 60 I=1,NQ1                                            00001140
ISN      117          DO 60 J=1,NP1                                            00001150
ISN      118          CALL LOC(I,J,IJ,NQ1,NP1,0)                               00001160
ISN      119       60 AM2(IJ)=AM1(I,J)                                         00001170
ISN      120          DO 61 J=1,NP1                                            00001180
ISN      121       61 DS(J)=D(J)/D1                                            00001190
ISN      122          CALL COBGIN(AM2,DS,DP,DW,DDW,DD,SDP,SW,SDD,D1,XM,YM,KB,NQ1,NP1,U,W00001200
                     1,T1,EPS,XLIM,XDEL,IPR)                                    00001210
                                                                                00001220
ISN      123          XJ12=YM                                                  00001230
ISN      124          D1=XM                                                    00001240
ISN      125          DO 62 J=1,NP2                                            00001250
ISN      126       62 D(J)=D1*DS(J)                                            00001260
ISN      127          HH=0                                                     00001270
ISN      128          DO 45 J=1,NP1                                            00001280
ISN      129          TC=T(J)                                                  00001290
ISN      130          IF(NT(J).NE.0) THEN                                      00001300
ISN      131          JJ=NT(J)                                                 00001310
ISN      132          TC=XI(JJ)                                                00001320
ISN      133          END IF                                                   00001330
ISN      134          CALL ENTH(NBTYP(J),TC,HT,P(J))                           00001340
ISN      135          DO 45 M=1,NL                                             00001350
ISN      136          CALL LOC(M,J,MJ,NL,NP1,0)                                00001360
ISN      137          H(MJ)=HT(M)                                              00001370
ISN      138       45 HH=HH+H(MJ)                                              00001380
                     C                                                          00001390
                     C NORMALIZE ENTHALPY MATRIX                                00001400
                     C                                                          00001410
                     C     HH=1./HH                                             00001420
                     C     NMN=NL*NP1
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                *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                C      DO 46 K=1,NDE                                                    00001430
                C   46 H(K)=H1*I(K)                                                    00001440
                       NW=NP1*NP2                                                       00001450
ISN      139           CALL J3MAT(AM2,H,D,DW,C,E,NO2,NP2,NW,MMAX)                       00001460
ISN      140           CALL ANBAL(C,E,V,A,Z,XJ3,NO2,NP2,MMAX)                           00001470
ISN      141           NR=(MMAX+1)*NO2                                                  00001480
ISN      142           NL=2*MMAX+1                                                      00001490
ISN      143           NC=NL*NP2                                                        00001500
ISN      144           DO 70 J=1,NP2                                                    00001510
ISN      145           ZZ=0                                                             00001511
ISN      146           DO 71 M=1,NL                                                     00001520
ISN      147           CALL LOC(M,J,MJ,NL,NP2,0)                                        00001530
ISN      148           ZZ=ZZ+Z(MJ)                                                      00001531
ISN      149        71 HI(M)=Z(MJ)*100                                                  00001540
ISN      150           ZZ=ZZ*100                                                        00001541
ISN      151           WRITE(NO,73) J,(HI(M),M=1,NL),ZZ                                 00001550
ISN      152        73 FORMAT(I3,6F8.2)                                                 00001560
ISN      153        70 CONTINUE                                                         00001570
ISN      154           WRITE(NO,74) (XI(K),K=1,N)                                       00001580
ISN      155        74 FORMAT(5F10.2)                                                   00001590
ISN      156           FJ=XJ12+XJ3                                                      00001600
                C                                                                      00001610
                C SET UP J45 MINIMIZATION TO DETERMINE TEMP EQUILIBRIUM                00001620
                C                                                                      00001630
ISN      157           IF(ISE) 98,97,98                                                 00001640
ISN      158        97 XJ4=0                                                            00001650
ISN      159           DO 80 J=1,NP2                                                    00001660
ISN      160           NS1=NI(J)                                                        00001670
ISN      161           IF(NS1.NE.0) THEN                                                00001680
ISN      162           END IF                                                           00001690
ISN      163        80 CONTINUE                                                         00001700
ISN      164           XJ5=0                                                            00001710
ISN      165           DO 81 J=1,NP2                                                    00001720
ISN      166           XJ6=1                                                            00001730
ISN      167           DO 82 M=1,NL                                                     00001740
ISN      168           CALL LOC(M,J,MJ,NL,NP2,0)                                        00001750
ISN      169        82 XJ6=XJ6*Z(MJ)                                                    00001760
ISN      170        81 XJ5=XJ5+(XJ6**2)*((EED)**2)                                      00001770
ISN      171           FJ=FJ+XJ4+XJ5                                                    00001780
ISN      172           WRITE(NO,96) FJ,XJ12,XJ3,XJ4,XJ5                                 00001790
ISN      173        96 FORMAT(5E14.5)                                                   00001800
ISN      174        98 RETURN                                                           00001810
ISN      175           END                                                              00001820
ISN      176                                                                           00001830

*STATISTICS*   SOURCE STATEMENTS = 176, PROGRAM SIZE = 13162 BYTES, PROGRAM NAME = CALCFX     PAGE:   13.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 3 ******
```

```
LEVEL 1.2.0 (SEPT 82)          OS FORTRAN          DATE: 1983 APR 27      TIME: 12:58:29      NAME: MAIN     PAGE:   17

OPTIONS IN EFFECT:  NOLIST NOMAP NOEDIT   GOSTMT NOREAL   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)   NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.......8

ISN       1          SUBROUTINE COGGIN(AM1,D,DP,DW,DDW,DD,GP,GW,GD,D1,XM,YM,KS,NO,NP,U,00000010
                    1W,T1,EPS,XLIM,XDEL,IPR)                                        00000020
                C   ...............................................................00000030
                C                                                                   00000040
                C   SUBROUTINE COGGIN                                             00000050
                C                                                                   00000060
                C   AUTHORS                                                        00000070
                C      R.GIRARD, F.FLAMENT, D.MORISSETTE                          00000080
                C      UNIVERSITE LAVAL                                           00000090
                C      MODIFIED BY D. MARCE    SASKATCHEWAN                       00000100
                C                                                                   00000110
                C   LAST UPDATE                                                    00000120
                C      MARCH 1983                                                 00000130
                C   ---------------------------------------------------------------00000140
                C                                                                   00000150
                C   PURPOSE                                                        00000160
                C      TO FIND THE MINIMUM OF AN UNCONSTRAINED, SINGLE VARIABLE,  00000170
                C      NONLINEAR FUNCTION USING THE COGGINS ALGORITHM             00000180
                C                                                                   00000190
                C   CALLING SEQUENCE                                              00000200
                C      CALL COGGIN (AM1,D,DP,DW,DDW,DD,GP,GW,GD,D1,KS,NO,NP,U,W,  00000210
                C                   T1,EPS,XLIM,XDEL,IPR)                          00000220
                C                                                                   00000230
                C   DESCRIPTION OF ARGUMENTS                                      00000240
                C      XM      I SEARCH VARIABLE                                   00000250
                C      YM      I CRITERION VALUE (J12)                             00000260
                C   ---------------------------------------------------------------00000270
                C      ALL OTHER ARGUMENTS ARE DESCRIBED IN SUBROUTINE CALCFY      00000280
                C                                                                   00000290
                C   REMARKS                                                        00000300
                C      SEE APPENDIX III OF THE USER'S MANUAL                       00000310
                C                                                                   00000320
                C   SUBROUTINES REQUIRED                                          00000330
                C      CALCFY                                                      00000340
                C                                                                   00000350
                C   ...............................................................00000360
                C                                                                   00000370
                C                                                                   00000380
ISN       2         DIMENSION AM1(1),D(1),DP(1),DW(1),DDW(1),DD(1),GP(1),GW(1),GD(1) 00000390
                    1,U(1),W(1)                                                     00000400
                C                                                                   00000410
                C      STEP 0                                                       00000420
                C                                                                   00000430
ISN       3         IOUT=6                                                        00000440
ISN       4         X1=D1                                                         00000450
ISN       5         DELX=XDEL                                                     00000460
ISN       6         D  (IPR.LE.3)WRITE (IOUT,1000)X1,XLIM,DELX                    00000470
                C   ***************************************************************00000480
ISN       8         CALL CALCFY(AM1,D,DP,DW,DDW,DD,GP,GW,GD,X1,Y1,KS,NO,NP,U,W,T1,EPS)00000490
                C   ***************************************************************00000500
ISN       9         IF(KS.EQ.1) RETURN                                            00000510
ISN      11         N=1                                                           00000520
ISN      12         IF (IPR.NE.1) GO TO 10                                        00000530
ISN      13         WRITE(IOUT,1010)                                              00000540
```

```
LEVEL 1.2.0 (DEC)  OS/VS2 MVT  DATE 79 MAR 27  TIME 12:56:09  NAME: COOPIN  PAGE:  18

                 *....*....1....*....2....*....3....*....4....*....5....*....6....*....7.*....8
ISN      14          WRITE(IOUT,1010)X1,Y1,DELX                                          00000540
                 C                                                                       00000550
                 C        STEP 1                                                         00000560
                 C                                                                       00000570
ISN      15      10  X2=X1+DELX                                                         00000580
                 C  ************************************************************       00000590
ISN      16          CALL CALCFY(AH1,D,DF,DW,DDW,DD,SF,SW,SD,X2,Y2,KS,NO,NF,U,W,T1,EPS)00000600
                 C  ************************************************************       00000610
ISN      17          IF(KS.EQ.1) RETURN                                                 00000620
ISN      19          K=K+1                                                              00000630
ISN      20          IF(IPR.LE.1)WRITE(IOUT,1020) X2,Y2,DELX                            00000640
                 C                                                                       00000650
                 C     CHANGE THE DIRECTION OF THE SEARCH IF Y2.GT.Y1                    00000660
                 C                                                                       00000670
ISN      22          IF(Y2.LE.Y1)GOTO 30                                                00000680
ISN      23          IF(K.GT.2)GOTO 40                                                  00000690
ISN      24          DELX=-DELX                                                         00000700
ISN      25          XM=X1                                                              00000710
ISN      26          X1=X2                                                              00000720
ISN      27          YM=Y1                                                              00000730
ISN      28          Y1=Y2                                                              00000740
ISN      29          X2=XM                                                              00000750
ISN      30          Y2=YM                                                              00000760
ISN      31          GO TO 30                                                           00000770
                 C                                                                       00000780
                 C        STEP 2                                                         00000790
                 C                                                                       00000800
ISN      32      20  DELX=2.*DELX                                                       00000810
ISN      33      30  X3=X2+DELX                                                         00000820
                 C  ************************************************************       00000830
ISN      34          CALL CALCFY(AH1,D,DF,DW,DDW,DD,SF,SW,SD,X3,Y3,KS,NO,NF,U,W,T1,EPS)00000840
                 C  ************************************************************       00000850
ISN      35          IF(KS.EQ.1) RETURN                                                 00000860
ISN      37          K=K+1                                                              00000870
ISN      38          IF(IPR.LE.1)WRITE(IOUT,1020) X3,Y3,DELX                            00000880
ISN      40          IF(Y3.GE.Y2)GOTO 40                                                00000890
ISN      41          X1=X2                                                              00000900
ISN      42          Y1=Y2                                                              00000910
ISN      43          X2=X3                                                              00000920
ISN      44          Y2=Y3                                                              00000930
ISN      45          GO TO 20                                                           00000940
                 C                                                                       00000950
                 C        STEP 3                                                         00000960
                 C                                                                       00000970
ISN      46      40  IF (IPR.LE.2)WRITE(IOUT,1030)                                     00000980
ISN      48      50  A=X1*X1                                                           00000990
ISN      49          B=X2*X2                                                            00001000
ISN      50          C=X3*X3                                                            00001010
ISN      51          BBX=B-C                                                            00001020
ISN      52          E=C-A                                                              00001030
ISN      53          F=A-B                                                              00001040
ISN      54          A=X2-X3                                                            00001050
ISN      55          B=X3-X1                                                            00001060
ISN      56          C=X1-X2                                                            00001070
ISN      57          X1=(BBX*Y1+E*Y2+F*Y3)/2.                                           00001080
ISN      58          X2=A*Y1+B*Y2+C*Y3                                                  00001090
```

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LEVEL 1.2.0 (SEPT 82)          V. COMEAU          DATE 1983 APR 27     TIME 12:50:29      NAME (COGGIN  PAGE   19

                 *....*....1.....2.....3.....4.....5.....6.....7.*.....8

ISN       59             XM=X1/X0                                                          00001100
                 C      ************************************************************      00001110
ISN       60             CALL CALCFX(A01,D,IF,I4,DDW,DD,SF,SW,SD,XM,YM,KS,NO,NF,U,W,T1,EPS)00001120
                 C      ************************************************************      00001130
ISN       61             IF(KS.EQ.1) RETURN                                                00001140
ISN       63             K=K+1                                                             00001150
ISN       64             IF(IFR.LE.2)WRITE(IOUT,1020)XM,YM                                 00001160
                                                                                           00001170
                 C                                                                         00001180
                 C        CHECK TO SEE IF ANY OF THE POINTS                                00001190
                 C        ARE WITHIN THE DESIRED ACCURACY.                                 00001200
                 C                                                                         00001210
ISN       66             IF(ABS(X1-XM).LE.XLIM) GOTO 120                                   00001220
ISN       67             IF(ABS(X2-XM).LE.XLIM) GOTO 120                                   00001230
ISN       68             IF(ABS(X3-XM).LE.XLIM) GOTO 120                                   00001240
                 C                                                                         00001250
                 C        SEARCH THE THREE POINTS WHICH STRADDLED MINIMUM                  00001260
                 C                                                                         00001270
ISN       69             IF((X1-XM)*(XM-X2))60,60,90                                       00001280
                 C                                                                         00001290
                 C        AND REORGANIZE THEM                                              00001300
                 C                                                                         00001310
ISN       70   60        IF(YM-Y2)70,70,80                                                 00001320
ISN       71   70        X1=X2                                                             00001330
ISN       72             Y1=Y2                                                             00001340
ISN       73             X2=XM                                                             00001350
ISN       74             Y2=YM                                                             00001360
ISN       75             GO TO 50                                                          00001370
ISN       76   80        X1=XM                                                             00001380
ISN       77             Y1=YM                                                             00001390
ISN       78             GO TO 50                                                          00001400
ISN       79   90        IF(YM-Y2)100,100,110                                              00001410
ISN       80   100       X3=X2                                                             00001420
ISN       81             Y3=Y2                                                             00001430
ISN       82             X2=XM                                                             00001440
ISN       83             Y2=YM                                                             00001450
ISN       84             GO TO 50                                                          00001460
ISN       85   110       X3=XM                                                             00001470
ISN       86             Y3=YM                                                             00001480
ISN       87             GO TO 50                                                          00001490
ISN       88   120       IF (IFR.LE.3)WRITE(IOUT,1040)K,YM,XM                              00001500
ISN       90             RETURN                                                            00001510
                 C                                                                         00001520
ISN       91   1000      FORMAT(1X,/,11X,17HCOGGINS ALGORITHM,/,2X,14HSTARTING VALUE       00001530
                +,5H X = ,F8.4,12H      XLIM = ,F7.5,12H      DELX = ,F7.5,/)             00001540
ISN       92   1010      FORMAT(7X,1HK,13X,1HF,13X,4HDELX)                                 00001550
ISN       93   1020      FORMAT(1X,F10.5,3X,E14.7,3X,F10.5)                                00001560
ISN       94   1030      FORMAT(1X,/,1X,13HQUADRATIC-FIT,/,7X,2HXM,12X,2HYM)               00001570
ISN       95   1040      FORMAT(1X,/,1X,I5,21H FUNCTION EVALUATIONS,0H    F = ,E14.7,     00001580
                +8H    X = ,F10.5)                                                        00001590
ISN       96             END

*STATISTICS*   SOURCE STATEMENTS = 86, PROGRAM SIZE = 3078 BYTES, PROGRAM NAME = COGGIN    PAGE   17.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 4 ******
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LEVEL 1.2.0 (SEPT 78)          OS FORTRAN          DATE= 1983 APR 27      TIME= 12:50:30      NAME= MAIN      PAGE=  20

OPTIONS IN EFFECT=  NOLIST NOMAP NOEDIT   NOSYM,NOREF   SOURCE   TERM   OBJECT FIXED  NOID,ST
                    OPTIMIZE(0)  LANGLVL(77) NOCHECK   FLAG(I)  NAME(MAIN )  LINECOUNT(60)

                 *....*....1.....2.....3.....4.....5.....6.....7.*.....8

                 C                                                                    00000010
                 C  COMPUTATION OF STREAM ANALYSIS AND STREAM ERROR MODEL              00000020
                 C                                                                    00000030
                 C STREAM ANALYSIS AND STATISTICS ARE DEVELOPED SOLELY FROM           00000040
                 C SATURATION CONDITIONS RELATING TO TEMPERATURE ONLY                 00000050
                 C                                                                    00000060
                 C LOGIC IS CONTROLLED BY BRINE CONDITION IN THE UNIT OPERATION       00000070
                 C                                                                    00000080
                 C IBC  CONDITION                                                     00000090
                 C  1  SATURATED NACL AND KCL                                         00000100
                 C  2  SATURATED KCL                                                  00000110
                 C  3  SATURATED NACL                                                 00000120
                 C  4  CLEAR BRINE SAT NACL AND KCL                                   00000130
                 C  5  CLEAR BRINE SAT KCL                                           00000140
                 C  6  CLEAR BRINE SAT NACL                                          00000150
                 C  7  CLEAR BRINE UNDERSATURATED                                    00000160
                 C  8  PURE WATER                                                    00000170
                 C                                                                    00000180
ISN         1           SUBROUTINE BC(M,ZM,IBC,ISF,T,ST,Z,SZ,ZN,ZK,ED)               00000190
ISN         2           DIMENSION Z(4),SZ(4),ZM(4)                                   00000200
ISN         3           XX1=X1(T,.001)                                               00000210
ISN         4           XX2=X2(T,.001)                                               00000220
ISN         5        50 GO TO (1,2,3,4,5,6,7,8) IBC                                  00000230
ISN         6         1 IF(ISF) 9,9,10                                               00000240
ISN         7        10 Z(1)=ZN                                                      00000250
ISN         8           Z(2)=ZK                                                      00000260
ISN         9           SZ(1)=ED                                                     00000270
ISN        10           SZ(2)=ED                                                     00000280
ISN        11        40 ZB=1 Z(1) Z(2)                                               00000290
ISN        12           Z(3)=XX1*ZB                                                  00000300
ISN        13           Z(4)=XX2*ZB                                                  00000310
ISN        14        31 SX1=DX1(T,.001)*ST                                           00000320
ISN        15           SX2=DX2(T,.001)*ST                                           00000330
ISN        16           SB=SQRT((SZ(1)**2)+(SZ(2)**2))                               00000340
ISN        17           SZ(3)=SQRT(((SX1*ZB)**2)+((XX1*SB)**2))                      00000350
ISN        18           SZ(4)=SX2*ZB                                                 00000360
ISN        19        11 Z(5)=1-Z(1)-Z(2)-Z(3)-Z(4)                                   00000370
ISN        20           SZ(5)=SQRT((SZ(1)**2)+(SZ(2)**2)+(SZ(3)**2)+(SZ(4)**2))      00000380
ISN        21           RETURN                                                       00000390
ISN        22         9 Z(1)=ZM(1)                                                   00000400
ISN        23           Z(2)=ZM(2)                                                   00000410
ISN        24           SZ(1)=ED                                                     00000420
ISN        25           SZ(2)=ED                                                     00000430
ISN        26           GO TO 30                                                     00000440
ISN        27         2 Z(1)=.001                                                    00000450
ISN        28           SZ(1)=.0005                                                  00000460
ISN        29           IF(ISF) 12,12,13                                             00000470
ISN        30        13 Z(2)=ZK                                                     00000480
ISN        31           SZ(2)=ED                                                     00000490
ISN        32           ZB=1-Z(1)-Z(2)                                               00000500
ISN        33           Z(3)=X1(T,.001)*ZB                                           00000510
ISN        34        14 XX2=X2(T,Z(3))                                               00000520
ISN        35           Z(4)=XX2*ZB                                                  00000530
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LEVEL 1.2.0 (SEPT 82)          OS FORTRAN          DATE 1983 APR 27      TIME 12:58:50      NAME BC      PAGE 21

                *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN      36          GO TO 21                                                    00000540
ISN      37       12 Z(2)=ZM(2)                                                  00000550
ISN      38          SZ(2)=ED                                                    00000560
ISN      39          Z(3)=ZM(3)                                                  00000570
ISN      40          ZB=1-Z(1) Z(2)                                              00000580
ISN      41          SZ(3)=ED                                                    00000590
ISN      42          GO TO 14                                                    00000600
ISN      43        3 Z(2)=.001                                                   00000610
ISN      44          SZ(2)=.0005                                                 00000620
ISN      45          IF(ISW) 15,15,16                                            00000630
ISN      46       16 Z(1)=ZN                                                     00000640
ISN      47          SZ(1)=ED                                                    00000650
ISN      48          ZB=1-Z(1) Z(2)                                              00000660
ISN      49          Z(4)=X2(I,.001)*ZB                                          00000670
ISN      50       17 XX1=Z1(I,Z(4))                                              00000680
ISN      51          Z(3)=XX1*ZB                                                 00000690
ISN      52          GO TO 31                                                    00000700
ISN      53       15 Z(1)=ZM(1)                                                  00000710
ISN      54          SZ(1)=ED                                                    00000720
ISN      55          Z(4)=ZM(4)                                                  00000730
ISN      56          ZB=1-Z(1) Z(2)                                              00000740
ISN      57          SZ(4)=ED                                                    00000750
ISN      58          GO TO 47                                                    00000760
ISN      59        4 Z(1)=.001                                                   00000770
ISN      60          Z(2)=.001                                                   00000780
ISN      61          SZ(1)=.0005                                                 00000790
ISN      62          SZ(2)=.0005                                                 00000800
ISN      63          Z(3)=X1(I,.001)                                             00000810
ISN      64          Z(4)=X2(I,.001)                                             00000820
ISN      65          SZ(3)=ABS(DX1(I,.001))*SI                                   00000830
ISN      66          SZ(4)=ABS(DX2(I,.001))*SI                                   00000840
ISN      67          GO TO 11                                                    00000850
ISN      68        5 Z(1)=.001                                                   00000860
ISN      69          Z(2)=.001                                                   00000870
ISN      70          SZ(1)=.0005                                                 00000880
ISN      71          SZ(2)=.0005                                                 00000890
ISN      72          IF(ISW) 18,18,27                                            00000900
ISN      73       27 Z(3)=X1(I,.001)                                             00000910
ISN      74          SZ(3)=ED                                                    00000920
ISN      75       19 Z(4)=Z2(I,Z(3))                                             00000930
ISN      76          SZ(4)=ABS(DZ2(I,Z(3)))*SI                                   00000940
ISN      77          GO TO 11                                                    00000950
ISN      78       18 Z(3)=ZM(3)                                                  00000960
ISN      79          SZ(3)=ED                                                    00000970
ISN      80          GO TO 19                                                    00000980
ISN      81        6 Z(1)=.001                                                   00000990
ISN      82          Z(2)=.001                                                   00001000
ISN      83          SZ(1)=.0005                                                 00001010
ISN      84          SZ(2)=.0005                                                 00001020
ISN      85          IF(ISW) 21,21,20                                            00001030
ISN      86       20 Z(4)=X2(I,.001)                                             00001040
ISN      87          SZ(4)=ED                                                    00001050
ISN      88       22 Z(3)=Z1(I,Z(4))                                             00001060
ISN      89          SZ(3)=ABS(DZ1(I,Z(4)))*SI                                   00001070
ISN      90          GO TO 11                                                    00001080
ISN      91       21 Z(4)=ZM(4)                                                  00001090
```

```
LEVEL 1.2.0 (561)   82)                    DATE 1983 APR 27     TIME 12:58:50     NAME PC      PAGE    22

                *....*....1....*....2....*....3....*....4....*....5....*....6....*....7.*....8

ISN         92          SZ(4)=ED                                                        00001100
ISN         93          GO TO 22                                                        00001110
ISN         94        7 Z(1)=.001                                                       00001120
ISN         95          Z(2)=.001                                                       00001130
ISN         96          SZ(1)=.0005                                                     00001140
ISN         97          SZ(2)=.0005                                                     00001150
ISN         98          SZ(3)=ED                                                        00001160
ISN         99          SZ(4)=ED                                                        00001170
ISN        100          IF(ISF) 24,24,23                                                00001180
ISN        101       23 Z(3)=X1(I,.001)                                                 00001190
ISN        102          Z(4)=X2(I,.001)                                                 00001200
ISN        103          GO TO 11                                                        00001210
ISN        104       24 Z(3)=ZM(3)                                                      00001220
ISN        105          Z(4)=ZM(4)                                                      00001230
ISN        106          GO TO 11                                                        00001240
ISN        107        0 DO 26 I=1,4                                                     00001250
ISN        108          Z(I)=0.                                                         00001260
ISN        109       26 SZ(I)=EPS                                                       00001270
ISN        110          Z(5)=1.0                                                        00001280
ISN        111          SZ(5)=EPS                                                       00001290
ISN        112          RETURN                                                          00001300
ISN        113          END                                                             00001310

*STATISTICS*   SOURCE STATEMENTS = 113, PROGRAM SIZE = 2752 BYTES, PROGRAM NAME = PC     PAGE    20.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 5 ******
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```
LEVEL 1.2.0 (SEPT 82)          OS/VS FORTRAN          DATE: 1983 NOV 27     TIME: 12:58:15      NAME: MAIN    PAGE:   23

OPTIONS IN EFFECT:  NOLIST NOMAP NO+SET   OOSIM2 NODECK   SOURCE   XERR   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) XWIDE   FLAG(I)  NAME(MAIN  ) LINECOUNT(60)

                 A....B....1....+....2....+....3....+....4....+....5....+....6....+....7.*....8

                 C                                                                          00000010
                 C   CONVERSION OF ELEMENT ANALYSIS TO STREAM ANALYSIS C/W STATISTICS        00000020
                 C                                                                          00000030
                 C                                                                          00000040
                 C USES MAIN CONDITIONS(SEE DC SUBROUTINE)                                  00000050
                 C                                                                          00000060
ISN        1         SUBROUTINE CONV(ZN,ZK,S,T,SZN,SZK,SS,ST,IRC,Z,SZ)                     00000070
ISN        2         DIMENSION Z(7),SZ(7)                                                  00000080
ISN        3       5 GO TO(1,2,3,4,4,4,4,8),IRC                                            00000090
ISN        4       1 XX1=X1(T,.001)                                                        00000100
ISN        5         SXX1=ABS(DX1(T,.001))*ST                                              00000110
ISN        6         XX2=X2(T,.001)                                                        00000120
ISN        7         SXX2=ABS(DX2(T,.001))*ST                                              00000130
ISN        8         U=1-(ZN+ZK)                                                           00000140
ISN        9         V=1-(XX1+XX2)                                                         00000150
ISN       10         ZB=U/V                                                                00000160
ISN       11         Z(3)=XX1*ZB                                                           00000170
ISN       12         Z(4)=XX2*ZB                                                           00000180
ISN       13         SZZ=SQRT((SZN**2)+(SZK**2))                                           00000190
ISN       14         SX=SQRT((SXX1**2)+(SXX2**2))                                          00000200
ISN       15         SB=SQRT(((V*SZZ)**2)+((U-SX)**2))/(V**2)                              00000210
ISN       16         SZ(3)=SQRT(((SXX1*ZB)**2)+((XX1*SB)**2))                              00000220
ISN       17         SZ(4)=SQRT(((SXX2*ZB)**2)+((XX2*SB)**2))                              00000230
ISN       18         Z(1)=ZN Z(3)                                                          00000240
ISN       19         SZ(1)=SQRT((SZN**2)+(SZ(3)**2))                                       00000250
ISN       20         Z(2)=ZK Z(4)                                                          00000260
ISN       21         SZ(2)=SQRT((SZK**2)+(SZ(4)**2))                                       00000270
ISN       22      10 Z(5)=1 Z(1) Z(2) Z(3) Z(4)                                            00000280
ISN       23         SZ(5)=0                                                               00000290
ISN       24         DO 9 M=1,4                                                            00000300
ISN       25       9 SZ(5)=SZ(5)+(SZ(M)**2)                                                00000310
ISN       26         SZ(5)=SQRT(SZ(5))                                                     00000320
ISN       27         RETURN                                                                00000330
ISN       28       2 ZB=1-S                                                                00000340
ISN       29         SB=SS                                                                 00000350
ISN       30         Z(2)=S .001                                                           00000360
ISN       31         Z(1)=.001                                                             00000370
ISN       32         Z(3)=ZN Z(1)                                                          00000380
ISN       33         Z(4)=ZK-Z(2)                                                          00000390
ISN       34         SZ(1)=.0005                                                           00000400
ISN       35         SZ(2)=SS                                                              00000410
ISN       36         SZ(3)=SZN                                                             00000420
ISN       37         SZ(4)=ABS(DX2(T,.001))*ST*ZB                                          00000430
ISN       38         GO TO 10                                                              00000440
ISN       39       3 ZB=1-S                                                                00000450
ISN       40         SB=SS                                                                 00000460
ISN       41         Z(1)=S .001                                                           00000470
ISN       42         Z(2)=.001                                                             00000480
ISN       43         Z(4)=ZK Z(2)                                                          00000490
ISN       44         Z(3)=ZN Z(1)                                                          00000500
ISN       45         SZ(1)=SB                                                              00000510
ISN       46         SZ(2)=.0005                                                           00000520
ISN       47         SZ(3)=SQRT((SZN**2)+(SZ(1)**2))                                       00000530
ISN       48         SZ(4)=SZK
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:50:32      NAME: CONV    PAGE:   24

                *....*....1....+....2....+....3....+....4....+....5....+....6....+....7.*....+....8

ISN       49          GO TO 10                                                              00000540
ISN       50        4 Z(1)=.001                                                             00000550
ISN       51          SZ(1)=.0005                                                           00000560
ISN       52          Z(2)=.001                                                             00000570
ISN       53          SZ(2)=.0005                                                           00000580
ISN       54          Z(3)=ZN*Z(1)                                                          00000590
ISN       55          Z(4)=ZK*Z(2)                                                          00000600
ISN       56          SZ(3)=SQRT((SZN**2)+(SZ(1)**2))                                       00000610
ISN       57          SZ(4)=SQRT((SZK**2)+(SZ(2)**2))                                       00000620
ISN       58          GO TO 10                                                              00000630
ISN       59        8 DO 16 M=1,4                                                           00000640
ISN       60          Z(M)=0.                                                               00000650
ISN       61       16 SZ(M)=.000005                                                         00000660
ISN       62          Z(5)=1                                                                00000670
ISN       63          SZ(5)=.000005                                                         00000680
ISN       64          RETURN                                                                00000690
ISN       65          END                                                                   00000700

*STATISTICS*   SOURCE STATEMENTS = 65, PROGRAM SIZE = 2154 BYTES, PROGRAM NAME = CONV    PAGE:   23.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION-6 ******
```

```
LEVEL 1.2.0 (SEPT 82)          VS FORTRAN          DATE: 1983 APR 27      TIME: 12:50:33      NAME: MAIN     PAGE:  25

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   OBJSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 ----+----1----+----2----+----3----+----4----+----5----+----6----+----7-|--+----8
                     C                                                                          00000010
                     C  CALCULATE ENTHALPY-MATRIX ELEMENTS AND STORE IN C AND E                 00000020
                     C  FOR PROBLEM C*Z = E WITH MIN JJ                                         00000030
                     C                                                                          00000040
                     C THE C MATRIX AND THE E VECTOR EXPRESS:                                   00000050
                     C THE ENTHALPY BALANCE                                                     00000060
                     C KCL AND NACL CONSERVATION                                                00000070
                     C FOR ALL NODES AND STREAMS                                                00000080
                     C                                                                          00000090
                           SUBROUTINE  THAT(AM1,H,D,DW,C,E,NJ,NF,NW,MMAX)                       00000100
ISN        1          COMMON NL,NO1,NO2,NO3,NF1,NF2,NF3,NMAX                                     00000110
ISN        2          DIMENSION AM1(1),H(1),DW(1),C(1),E(1),A(50),D(1),DW(1)                     00000120
ISN        3          DIMENSION IR(20),IC(40)                                                    00000130
ISN        4          EPS=1.0E-4                                                                 00000140
ISN        5       99 EPS=1.0E-4                                                                 00000150
                     C  COMPUTE LHS,RHS                                                         00000160
ISN        6          NL=2*MMAX+1                                                                00000170
ISN        7          NR=(MMAX+1)*NO                                                             00000180
ISN        8          NC=NL*NF                                                                   00000190
ISN        9          DO 10,I=1,NR                                                               00000200
ISN       10       10 E(I)=0                                                                     00000210
ISN       11          IJ=NR*NC                                                                   00000220
ISN       12          DO 11, J=1,IJ                                                              00000230
ISN       13       11 C(J)=0                                                                     00000240
ISN       14       15 DO 1 I=1,NO                                                                00000250
ISN       15          DO 3 M=1,NL                                                                00000260
ISN       16          DO 12 K=1,NR                                                               00000270
ISN       17       12 A(K)=0                                                                     00000280
                     C                                                                          00000290
                     C  COMPUTE ENTHALPY TENSOR                                                 00000300
                     C                                                                          00000310
ISN       18          DO 2 K=1,NF                                                                00000320
ISN       19          CALL LOC(M,K,MK,NL,NR1,0)                                                  00000330
ISN       20          NFW=NF+NW                                                                  00000340
ISN       21          CALL LOC(I,K,IK,NO1,NF1,0)                                                 00000350
ISN       22        2 A(K)=A(K)+AM1(IK)*(D(K)+DW(K))*H(MK)                                       00000360
ISN       23          DO 3 J=1,NF                                                                00000370
ISN       24          CALL LOC(M,J,MJ,NL,NC,0)                                                   00000380
ISN       25          CALL LOC(I,MJ,IJ,NR,NC,0)                                                  00000390
ISN       26        3 C(IJ)=A(J)                                                                 00000400
ISN       27        1 CONTINUE                                                                   00000410
ISN       28          DO 5 I=1,NO                                                                00000420
ISN       29          E(I)=0                                                                     00000430
ISN       30          NS1=NF+1                                                                   00000440
ISN       31          DO 6 K=NS1,NFW                                                             00000450
ISN       32          CALL LOC(NL,K,MK,NL,NF1,0)                                                 00000460
ISN       33          CALL LOC(I,K,IK,NO1,NF1,0)                                                 00000470
ISN       34        5 E(I)=E(I)-AM1(IK)*DW(K)*H(MK)                                              00000480
                     C                                                                          00000490
                     C  COMPUTE CONSERVATION OF NACL, KCL ETS FOR MATRIX C AND VECTOR E          00000500
                     C                                                                          00000510
ISN       35          DO 7 I=1,NO                                                                00000520
ISN       36          DO 13 K=1,NF                                                               00000530
ISN       37       13 A(K)=0
```

```
LEVEL 1.2.0 (SEPT 82)          VS FORTRAN          DATE= 1983 APR 27     TIME= 12:58:33'     NAME= J3MAT   PAGE=   26

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN       38            DO 8 K=1,N                                                    00000540
ISN       39            CALL LOC(I,K,IK,NU1,NR1,0)                                    00000550
ISN       40          8 A(K)=A(K)+AM1(IK)*(D(K)+DW(K))                                00000560
ISN       41            DO 7 J=1,NR                                                   00000570
ISN       42            DO 7 M1=1,MMAX                                                00000580
ISN       43            M2=M1+MMAX                                                    00000590
ISN       44            NIM=M1*NO+I                                                   00000600
ISN       45            CALL LOC(M1,J,MIJ,NL,NR,0)                                    00000610
ISN       46            CALL LOC(M2,J,M2J,NL,NR,0)                                    00000620
ISN       47            CALL LOC(NIM,MIJ,IJ1,NR,NC,0)                                 00000630
ISN       48            CALL LOC(NIM,M2J,IJ2,NR,NC,0)                                 00000640
ISN       49            C(IJ1)=A(J)                                                   00000650
ISN       50            C(IJ2)=A(J)                                                   00000660
ISN       51          7 E(NIM)=0                                                      00000670
ISN       52            GO TO 16                                                      00000680
                  C                                                                   00000690
                  C THE FOLLOWING IS TEST LOGIC TO CHECK MATRIX ILL CONDITIONING      00000700
                  C                                                                   00000710
ISN       53         35 DO 20 J=1,NC                                                  00000720
ISN       54            WRITE(NO,*) J                                                 00000730
ISN       55            DO 30 I=1,NR                                                  00000740
ISN       56            CALL LOC(I,J,IJ,NR,NC,0)                                      00000750
ISN       57         30 A(I)=C(IJ)                                                    00000760
ISN       58            WRITE(6,21) (A(I),I=1,NR)                                     00000770
ISN       59         21 FORMAT(5E14.5)                                                00000780
ISN       60            WRITE(6,22)                                                   00000790
ISN       61         22 FORMAT(/)                                                     00000800
ISN       62         20 CONTINUE                                                      00000810
ISN       63            CALL MFGR(0,NR,NR,EPS,IRANK,IA,IC)                            00000820
ISN       64            WRITE(6,*) IRANK                                              00000830
ISN       65            WRITE(6,*) IR                                                 00000840
ISN       66            WRITE(6,*) IC                                                 00000850
ISN       67            DO 23 J=1,NC                                                  00000860
ISN       68            WRITE(6,*) J,IC(J)                                            00000870
ISN       69            DO 31 I=1,NR                                                  00000880
ISN       70            CALL LOC(I,J,IJ,NR,NC,0)                                      00000890
ISN       71         31 A(I)=C(IJ)                                                    00000900
ISN       72            WRITE(6,21) (A(I),I=1,NR)                                     00000910
ISN       73            WRITE(6,22)                                                   00000920
ISN       74         23 CONTINUE                                                      00000930
ISN       75            STOP                                                          00000940
ISN       76         16 RETURN                                                        00000950
ISN       77            END                                                           00000960

*STATISTICS*    SOURCE STATEMENTS = 77, PROGRAM SIZE = 3812 BYTES, PROGRAM NAME = J3MAT     PAGE=   25.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 7 ******
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```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:34      NAME: MAIN     PAGE:   27

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   NOSTMT NODECK   SOURCE   ITERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 #....#....1....+....2....+....3....+....4....+....5....+....6....+....7.#....+....8

                       C                                                                          00000010
                       C  WATER BALANCE TO DETERMINE DW BY LAGRANGIAN MULTIPLIER METHOD            00000020
                       C                                                                          00000030
ISN         1              SUBROUTINE WTBAL (AM1,U,W,DW,NO,NP)                                    00000040
ISN         2              DIMENSION AM1(1),U(1),W(1),X(50),W1(50),U1(50),B(210),AUX(50)          00000050
                          1,DW(1)                                                                 00000060
ISN         3            3 NO=6                                                                   00000070
ISN         4              EPS=1.0E-4                                                             00000080
ISN         5              DO 1 J=1,NP                                                            00000090
ISN         6              U1(J)=1/U(J)                                                           00000100
ISN         7            1 W1(J)=W(J)*U1(J)                                                       00000110
ISN         8              DO 2 I=1,NO                                                            00000120
ISN         9              X(I)=0                                                                 00000130
ISN        10              DO 2 K=1,NP                                                            00000140
ISN        11              CALL LOC(I,K,IK,NO,NP,0)                                               00000150
ISN        12            2 X(I)=X(I)+AM1(IK)*W1(K)                                                00000160
ISN        13              CALL MATRX(AM1,U1,S,NO,NP)                                             00000170
ISN        14              CALL GELS(X,B,NO,1,EPS,IER,AUX)                                        00000180
ISN        15              IF(IER) 7,8,10                                                         00000190
ISN        16            7 WRITE(NO,9)                                                            00000200
ISN        17            9 FORMAT(' INCIDENT MATRIX WTBAL  ILL CONDITIONED')                      00000210
ISN        18              STOP                                                                   00000220
ISN        19           10 WRITE(NO,11) IER                                                       00000230
ISN        20           11 FORMAT(' CONDITIONING WARNING STEP ',I3,'WTBAL')                       00000240
ISN        21            8 CALL CORR(U1,AM1,X,DW,NO,NP)                                           00000250
ISN        22              DO 6 J=1,NP                                                            00000260
ISN        23            5 DW(J)=W1(J)-DW(J)                                                      00000270
ISN        24            4 RETURN                                                                 00000280
ISN        25              END                                                                    00000290

*STATISTICS*    SOURCE STATEMENTS = 25, PROGRAM SIZE = 2956 BYTES, PROGRAM NAME = WTBAL     PAGE:   27.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 8 *******
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LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1993 APR 27     TIME: 12:50:34      NAME: MAIN     PAGE:   28

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                       C
                       C  FEED-WATER BALANCE; OVERALL J12 MINIMIZATION                                    00000300
                       C                                                                                  00000310
                                                                                                          00000320
ISN         1              SUBROUTINE CALCFY(AM1,D,DP,DW,DDW,DD,GP,GW,GD,X,Y,KS,NQ,NP,U,W,             00000330
                          1T1,EPS)                                                                        00000340
ISN         2              COMMON NL,NQ1,NQ2,NQ3,NP1,NP2,NP3,MMAX                                      00000350
ISN         3              DIMENSION AM1(1),D(1),DP(1),DW(1),DD(1),GP(1),GW(1),GD(1),U(1),             00000360
                          1W(1),DDW(1)                                                                    00000370
ISN         4            4 T1=0                                                                        00000380
ISN         5              D1=X                                                                        00000390
ISN         6              DO 1 J=1,NP1                                                                00000400
ISN         7              U(J)=0                                                                      00000410
ISN         8            1 W(J)=0                                                                      00000420
ISN         9              DO 2 J=1,NP                                                                 00000430
ISN        10              IF(J.LE.NP2) THEN                                                           00000440
ISN        11              U(J)=U(J)+1/((GD(J)**2)*(D(J)**2)*(D1**2))+1/(GP(J)**2)                     00000450
ISN        12              W(J)=W(J)+DD(J)/((GD(J)**2)*D(J)*D1)+(DP(J)-D(J)*D1)/(GP(J)**2)             00000460
ISN        13              T1=T1+((D(J)**2)*D1*D1-2*D(J)*D1*DP(J))/(GP(J)**2)                          00000470
ISN        14              T1=T1+(DD(J)**2)/(GD(J)**2)+(DP(J)**2)/(GP(J)**2)                           00000480
ISN        15              END IF                                                                      00000490
ISN        16              U(J)=U(J)+1/(GW(J)**2)                                                      00000500
ISN        17              W(J)=W(J)+DDW(J)/(GW(J)**2)                                                 00000510
ISN        18              T1=T1+(DDW(J)**2)/(GW(J)**2)                                                00000520
ISN        19            2 CONTINUE                                                                    00000530
ISN        20              CALL WTBAL(AM1,U,W,DW,NQ,NP)                                                00000540
ISN        21              WRITE(6,*) (DW(K),K=1,NP1)                                                  00000550
ISN        22              Y=T1                                                                        00000560
ISN        23              KS=2                                                                        00000570
ISN        24              DO 3 J=1,NP                                                                 00000580
ISN        25            3 Y=Y+DW(J)*U(J)*DW(J)-2*W(J)*DW(J)                                           00000590
ISN        26            5 RETURN                                                                      00000600
ISN        27              END                                                                         00000610

*STATISTICS*   SOURCE STATEMENTS = 27, PROGRAM SIZE = 2150 BYTES, PROGRAM NAME = CALCFY     PAGE:   28.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 9 *******
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PRINTED IN CANADA
R. - CRAIN INC.

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:35      NAME: MAIN     PAGE:   29

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                       C
                       C--J3 MINIMIZATION OR ANALYSIS BALANCE                                  00000620
                       C                                                                       00000630
                       C THIS SUBROUTINE SOLVES FOR COHERENT ANALYSIS                          00000640
                       C USING THE LAGRANGIAN CAPACITY METHOD                                  00000650
                       C                                                                       00000660
                                                                                               00000670
ISN        1                SUBROUTINE ANBAL(C,E,V,ZZD,ZZ,XJ3,NO,NP,M)                     00000680
ISN        2                DIMENSION C(1),V(1),ZZD(1),ZZ(1),S(5050),U(100),E(1),X(100)    00000690
                           1,AUX(100)                                                          00000700
ISN        3                NO=6                                                            00000710
ISN        4                EPS=1.0E-4                                                      00000720
ISN        5                NR=(M+1)*NO                                                     00000730
ISN        6                NC=NP*(2*M+1)                                                   00000740
                       C--COMPUTE C*ZZD-E=X                                                  00000750
ISN        7                CALL MPRD(C,ZZD,X,NR,NC,0,0,1)                                  00000760
ISN        8                DO 7 I=1,NR                                                     00000770
ISN        9              7 X(I)=X(I)-E(I)                                                  00000780
                       C  COMPUTE (C*V*CT)*U=X  CT - TRANSPOSE OF C                          00000790
ISN       10                CALL MATRX(C,V,S,NR,NC)                                         00000800
ISN       11                CALL GELG4(X,S,NR,1,EPS,IER,AUX)                                00000810
ISN       12                IF(IER) 3,4,9                                                   00000820
ISN       13              3 WRITE(NO,5) IER                                                 00000830
ISN       14              5 FORMAT(' ERRCODE= ',I3,'ILL COND MATRIX ANBAL')                 00000840
ISN       15                STOP                                                            00000850
ISN       16              9 WRITE(NO,6) IER                                                 00000860
ISN       17              6 FORMAT('-WARNING STEP ',I3,' ANBAL MATRIX')                     00000870
ISN       18              4 CALL CORR(V,C,X,ZZ,NR,NC)                                     00000880
ISN       19                DO 8 J=1,NC                                                     00000890
ISN       20              8 ZZ(J)=ZZD(J)-ZZ(J)                                              00000900
ISN       21                XJ3=0                                                           00000910
ISN       22                DO 1 J=1,NC                                                     00000920
ISN       23              1 XJ3=XJ3+((ZZ(J)-ZZD(J))**2)/U(J)                              00000930
ISN       24                RETURN                                                          00000940
ISN       25                END                                                             00000950

*STATISTICS*   SOURCE STATEMENTS = 25, PROGRAM SIZE = 22274 BYTES, PROGRAM NAME = ANBAL     PAGE:   29.

*STATISTICS*  NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 10 ******
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LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:35      NAME: MAIN     PAGE:   30

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN         1          SUBROUTINE CORR(V,C,U,X,NR,NC)                                    00000960
ISN         2          DIMENSION C(1),V(1),X(1),U(1)                                     00000970
ISN         3          DO 1 J=1,NC                                                       00000980
ISN         4          X(J)=0                                                            00000990
ISN         5          DO 2 K=1,NR                                                       00001000
ISN         6          CALL LOC(K,J,KJ,NR,NC,0)                                          00001010
ISN         7        2 X(J)=X(J)+V(J)*C(KJ)*U(K)                                         00001020
ISN         8       -1 CONTINUE                                                        00001030
ISN         9          RETURN                                                          00001040
ISN        10          END                                                             00001050

*STATISTICS*   SOURCE STATEMENTS = 10, PROGRAM SIZE = 662 BYTES, PROGRAM NAME = CORR     PAGE:   30.

*STATISTICS*   NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 11 ******
```

PRINTED IN CANADA
A. L. DRAIN INC.

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:35      NAME: MAIN     PAGE:   31

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                 C                                                                  00001060
                 C  COMPUTE (C*V)*CT  CT = TRANSPOSE OF C                           00001070
                 C  AND STORE AS A SYMMETRIC MATRIX S                               00001080
                 C                                                                  00001090
ISN         1        SUBROUTINE MATRX(C,V,S,NR,NC)                                 00001100
ISN         2        DIMENSION C(1),V(1),S(1)                                      00001110
ISN         3        DO 1 I=1,NR                                                   00001120
ISN         4        DO 1 J=I,NR                                                   00001130
ISN         5        CALL LOC(I,J,IJ,NR,NR,1)                                      00001140
ISN         6        S(IJ)=0                                                       00001150
ISN         7        DO 2 K=1,NC                                                   00001160
ISN         8        CALL LOC(I,K,IK,NR,NC,0)                                      00001170
ISN         9        CALL LOC(J,K,JK,NR,NC,0)                                      00001180
ISN        10      2 S(IJ)=S(IJ)+C(IK)*V(K)*C(JK)                                  00001190
ISN        11      1 CONTINUE                                                      00001200
ISN        12        RETURN                                                        00001210
ISN        13        END                                                           00001220

*STATISTICS*   SOURCE STATEMENTS = 13, PROGRAM SIZE = 800 BYTES, PROGRAM NAME = MATRX     PAGE:   31.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 12 ******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:35      NAME: MAIN     PAGE:   32

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   OSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                       C                                                          00001230
                       C  CALCULATE PULP FLOW AND STATISTICS                      00001240
                       C                                                          00001250
ISN        1                SUBROUTINE PULP(S,F,T,ZN,SS,SF,DP,SP)                00001260
ISN        2              1.RRB=RB(T,ZN)                                         00001270
ISN        3                RS=1.984                                             00001280
ISN        4                Q=RB-(RB-RRB)*S                                      00001290
ISN        5                CV=RRB*8/Q                                           00001300
ISN        6                R=RS*CV+RRB*(1-CV)                                   00001310
ISN        7                DRDS=(RRB*RS/(Q*Q))*(RS-RRB)                         00001320
ISN        8                SR=DRDS*SS                                           00001330
ISN        9                DP=59.898*R*F                                        00001340
ISN       10                SP=59.898*SQRT(((R*SF)**2)+((F*SR)**2))              00001350
ISN       11              2 RETURN                                               00001360
ISN       12                END                                                  00001370

*STATISTICS*   SOURCE STATEMENTS = 12, PROGRAM SIZE = 594 BYTES, PROGRAM NAME = PULP     PAGE:   32.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 13 *******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:36      NAME: MAIN     PAGE:   33

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                      OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*....1....+....2....+....3....+....4....+....5....+....6....+....7.*....+....8

                       C                                                                      00001380
                       C  COMPUTE DILUTION FROM % SOLIDS BY WEIGHT.                           00001390
                       C                                                                      00001400
ISN         1              SUBROUTINE DIL(S,T,ZN,ZK,SS,ST,SZN,SZK,IBC,DD,SDD)               00001410
ISN         2          8 GO TO (1,1,1,2,2,2,2,3),IBC                                        00001420
ISN         3          1 X3=ZN                                                              00001430
ISN         4            X4=ZK                                                              00001440
ISN         5            S3=SZN                                                             00001450
ISN         6            S4=SZK                                                             00001460
ISN         7            GO TO 7                                                            00001470
ISN         8          2 S=0                                                                00001480
ISN         9            GO TO 1                                                            00001490
ISN        10          7 Q=S+X3+X4                                                          00001500
ISN        11            DD=(1.0/Q)*1                                                       00001510
ISN        12            SDD=SQRT((SS**2)+(S3**2)+(S4**2))/(Q**2)                           00001520
ISN        13            RETURN                                                             00001530
ISN        14          3 DD=1.0E+75                                                         00001540
ISN        15            SDD=1.0E+75                                                        00001550
ISN        16            RETURN                                                             00001560
ISN        17            END                                                                00001570

*STATISTICS*   SOURCE STATEMENTS = 17, PROGRAM SIZE = 644 BYTES, PROGRAM NAME = DIL     PAGE:   33.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 14 *******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:36      NAME: MAIN    PAGE:   34

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   EDSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

                       C                                                                    00001580
                       C  INITIALIZE FLOATING POINT ARRAYS                                  00001590
                       C                                                                    00001600
ISN         1                SUBROUTINE DINIT(A,N,X)                                       00001610
ISN         2                DIMENSION A(1)                                                00001620
ISN         3                DO 1 I=1,N                                                    00001630
ISN         4              1 A(I)=X                                                        00001640
ISN         5                RETURN                                                        00001650
ISN         6                END                                                           00001660

*STATISTICS*   SOURCE STATEMENTS = 6, PROGRAM SIZE = 318 BYTES, PROGRAM NAME = DINIT     PAGE:   34.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 15 ******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:36      NAME: MAIN     PAGE:   35

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*....1....+....2....+....3....+....4....+....5....+....6....+....7.*....+....8

                       C                                                                    00001670
                       C  INITIALIZE FIXED POINT ARRAYS                                     00001680
                       C                                                                    00001690
ISN          1               SUBROUTINE NINIT(L,M,N)                                       00001700
ISN          2               DIMENSION L(1)                                                00001710
ISN          3               DO 1 I=1,M                                                    00001720
ISN          4             1 L(I)=N                                                        00001730
ISN          5               RETURN                                                        00001740
ISN          6               END                                                           00001750

*STATISTICS*   SOURCE STATEMENTS = 6, PROGRAM SIZE = 318 BYTES, PROGRAM NAME = NINIT    PAGE:   35.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 16 ******
```

OPTIONS IN EFFECT: NOLIST NOMAP NOXREF GOSTMT NODECK SOURCE TERM OBJECT FIXED NOTEST
OPTIMIZE(0) LANGLVL(77) NOFIPS FLAG(I) NAME(MAIN) LINECOUNT(60)

```
                *....*...1.....2.....3.....4.....5.....6.....7.*.....8
                C                                                          00001760
                C  CONVERSION OF FLOW TO PULP FLOW OR WATER FLOW FOR       00001770
                C   - DRINE, WATER, VAPOR AND STEAM                        00001780
                C                                                          00001790
ISN         1       SUBROUTINE VOL(F,T,SF,ST,IST,DP,SP,DDW,SW)             00001800
ISN         2     5 GO TO (1,2,3,4,4), IST                                 00001810
ISN         3     2 ZN=X1(T,.001)                                          00001820
ISN         4       RRB=RB(T,ZN)                                           00001830
ISN         5       DP=59.898*RRB*F                                        00001840
ISN         6       ZK=X2(T,.001)                                          00001850
ISN         7       Q=1-ZN-ZK                                              00001860
ISN         8       DDW=Q*DP                                               00001870
ISN         9       SR=1.125E-4*ST                                         00001880
ISN        10       SP=59.898*SQRT(((RRB*SF)**2)+((F*SR)**2))              00001890
ISN        11       SN=DX1(T,.001)*ST                                      00001900
ISN        12       SK=DX2(T,.001)*ST                                      00001910
ISN        13       SQ=SQRT((SN**2)+(SK**2))                               00001920
ISN        14       SW=SQRT(((SQ*F)**2)+((SF*Q)**2))                       00001930
ISN        15     1 RETURN                                                 00001940
ISN        16     3 DP=0                                                   00001950
ISN        17       SP=0                                                   00001960
ISN        18       R=RW(T)                                                00001970
ISN        19       DDW=59.898*R*F                                         00001980
ISN        20       SW=59.898*R*SF                                         00001990
ISN        21       RETURN                                                 00002000
ISN        22     4 DP=0                                                   00002010
ISN        23       SP=0                                                   00002020
ISN        24       DDW=.06*F                                              00002030
ISN        25       SW=.06*SF                                              00002040
ISN        26       RETURN                                                 00002050
ISN        27       END                                                    00002060
```

STATISTICS SOURCE STATEMENTS = 27, PROGRAM SIZE = 1044 BYTES, PROGRAM NAME = VOL PAGE: 36.

STATISTICS NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 17 ******

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:36      NAME: MAIN    PAGE:   37

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN         1          SUBROUTINE ENTH(IST,T,H,P)                          00002070
                      C                                                   00002080
                      C  ENTHALPY OF STREAM COMPONENTS                    00002090
                      C                                                   00002100
ISN         2          DIMENSION H(1)                                      00002110
ISN         3          T1=1.8*T+32.                                        00002120
ISN         4          H(2)=(.15947+.00002801*T1)*(T1-32)*2.3259           00002130
ISN         5          H(1)=(.20292+.0000399*T1)*(T1-32)*2.3259            00002140
ISN         6          H(3)=H(1)+83.41                                     00002150
ISN         7          H(4)=H(2)+249.55                                    00002160
ISN         8          H(5)=2.3373*(T1-32.013)                             00002170
ISN         9          GO TO (1,1,1,2,3),IST                               00002180
ISN        10        2 H(5)=H(5)+2552.26*EXP(-.00057307*T1)                00002190
ISN        11          RETURN                                              00002200
ISN        12        3 H(5)=HSTM(T,P)                                      00002210
ISN        13        1 RETURN                                              00002220
ISN        14          END                                                 00002230

*STATISTICS*   SOURCE STATEMENTS = 14, PROGRAM SIZE = 646 BYTES, PROGRAM NAME = ENTH     PAGE:   37.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 18 *******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:59:36      NAME: MAIN     PAGE:   38

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                      C                                                                  00002240
                      C PRINT SUBROUTINE FOR ANALYBIS TABLE                              00002250
                      C                                                                  00002260
ISN         1             SUBROUTINE ANTAB                                             00002270
ISN         2             COMMON NL,NQ1,NQ2,NQ3,NP1,NP2,NP3,MMAX                       00002280
ISN         3             COMMON NTYPE(20),NSTYP(50),NBC(50),F(50),R(50),SF(50),SR(50),00002290
                         1       NODE(20),DSCND(20,10),NSTR(50),DSCST(10,50),AM1(20,50),00002300
                         2      T(50),P(50),ST(50),SP(50),ZD(3,50),SZ(3,50),NRF(50),  00002310
                         3       NTP(50),NZ(50),A(350),V(350),Z(350),ZM(7),SZM(7),D(50),00002320
                         4       DP(50),DW(50),DDW(50),DD(50),SDP(50),SW(50),SDD(50),  00002330
                         5       U(1000),W(50),H(350),C(9999),E(110),TH(100),ED(50),HT(7)00002340
                         6      ,EED,NT(50),EPS,NNT                                    00002350
ISN         4             DIMENSION Z1(7),A1(7),S1(7),Y(10),G(10)                      00002360
ISN         5             NO=10                                                        00002370
ISN         6             LC=52                                                        00002380
ISN         7             WRITE(NO,1)                                                  00002390
ISN         8           1 FORMAT('1KILBORN(SASKATCHEWAN) LTD.      POTASH CRYSTALLISER00002400
                         1 SIMULATION'/47X,'ANALYBIS TABLE'//24X,' *.....SOLIDS.....00002410
                         2..*  *.....BRINE.....*'/)                                   00002420
ISN         9             WRITE(NO,2)                                                  00002430
ISN        10           2 FORMAT(25X,' NACL      KCL    MGCL2  SOLIDS   NACL      KCL',00002440
                         1'   MGCL2      H2O    BRINE     S.G.'/)                      00002450
ISN        11             IBL=1                                                      00002460
ISN        12             IF(NL.EQ.5) IBL=0                                          00002470
ISN        14             DO 3 J=1,NP2                                               00002480
ISN        15             DO 4 M=1,NL                                                00002490
ISN        16             CALL LOC(M,J,MJ,NL,NP2,0)                                  00002500
ISN        17             Z1(M)=Z(MJ)                                                00002510
ISN        18             S1(M)=SQRT(V(MJ))                                          00002520
ISN        19           4 A1(M)=A(MJ)                                                00002530
ISN        20             IF (IBL.NE.0) GO TO 99                                     00002540
ISN        21             XNS=Z1(1)*100                                              00002550
ISN        22             XKS=Z1(2)*100                                              00002560
ISN        23             XMS=0                                                      00002570
ISN        24             XSOL=XNS+XKS                                               00002580
ISN        25             XND=Z1(3)*100                                              00002590
ISN        26             XKD=Z1(4)*100                                              00002600
ISN        27             XMD=0                                                      00002610
ISN        28             H2O=100-XND-XKD-XSOL                                       00002620
ISN        29             BRINE=H2O+XND+XKD                                          00002630
ISN        30             TC=T(J)                                                    00002640
ISN        31             IF(NT(J).NE.0) THEN                                        00002650
ISN        32             JJ=NT(J)                                                   00002660
ISN        33             TC=TH(JJ)                                                  00002670
ISN        34             END IF                                                     00002680
ISN        35             XN=Z1(3)/(1-Z1(1)-Z1(2))                                   00002690
ISN        36             RRB=RB(TC,XN)                                              00002700
ISN        37             ZB=Z1(1)+Z1(2)                                             00002710
ISN        38             RR=1.984*ZB+(1-ZB)*RRB                                     00002720
ISN        39             IF(LO.LT.6) THEN                                           00002730
ISN        40             WRITE(NO,1)                                                00002740
ISN        41             WRITE(NO,2)                                                00002750
ISN        42             LC=52                                                      00002760
```

```
                *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN      43          END IF                                                  00002770
ISN      44          WRITE(NO,6) (DSCST(I,J),I=1,10),XNS,XKS,XMS,XSOL,XND,XKD,XMD,H2O,  00002780
                    1BRINE,RR                                               00002790
ISN      45          LC=LC-2                                                 00002800
ISN      46          IF(NZ(J),NE.0) THEN                                     00002810
ISN      47          ANS=A1(1)*100                                           00002820
ISN      48          AKS=A1(2)*100                                           00002830
ISN      49          AMS=0                                                   00002840
ISN      50          ASOL=ANS+AKS                                            00002850
ISN      51          AND=A1(3)*100                                           00002860
ISN      52          AKD=A1(4)*100                                           00002870
ISN      53          AMD=0                                                   00002880
ISN      54          AH2O=100-ASOL-AND-AKD                                   00002890
ISN      55          ABRIN=AH2O+AND+AKD                                      00002900
ISN      56          AN=A1(3)/(1-A1(1)-A1(2))                                00002910
ISN      57          RRB=RB(T(J),AN)                                         00002920
ISN      58          ZB=A1(1)+A1(3)                                          00002930
ISN      59          ARR=1.984*ZB+(1-ZB)*RRB                                 00002940
ISN      60          WRITE(NO,7) ANS,AKS,AMS,ASOL,AND,AKD,AMD,AH2O,ABRIN,ARR  00002950
ISN      61          LC=LC-4                                                 00002960
ISN      62          Y(1)=XNS-ANS                                            00002970
ISN      63          Y(2)=XKS-AKS                                            00002980
ISN      64          Y(4)=XSOL-ASOL                                          00002990
ISN      65          Y(5)=XND-AND                                            00003000
ISN      66          Y(6)=XKD-AKD                                            00003010
ISN      67          Y(8)=H2O-AH2O                                           00003020
ISN      68          Y(9)=BRINE-ABRIN                                        00003030
ISN      69          Y(10)=RR-ARR                                            00003040
ISN      70          Y(3)=0                                                  00003050
ISN      71          Y(7)=0                                                  00003060
ISN      72          WRITE(NO,8) (Y(K),K=1,10)                               00003070
ISN      73          G(1)=S1(1)*100                                          00003080
ISN      74          G(2)=S1(2)*100                                          00003090
ISN      75          G(3)=0                                                  00003100
ISN      76          G(4)=SR(J)*100                                          00003110
ISN      77          G(5)=S1(3)*100                                          00003120
ISN      78          G(6)=S1(4)*100                                          00003130
ISN      79          G(7)=0                                                  00003140
ISN      80          G(8)=S1(5)*100                                          00003150
ISN      81          G(9)=SR(J)*100                                          00003160
ISN      82          G(10)=(1.984-RRD)*SR(J)                                 00003170
ISN      83          WRITE(NO,9) (G(K),K=1,10)                               00003180
ISN      84          DO 10 K=1,10                                            00003190
ISN      85          ZG=0                                                    00003200
ISN      86          IF(G(K),NE.0) THEN                                      00003210
ISN      87          ZG=ABS(Y(K)/G(K))*100                                   00003220
ISN      88          END-IF                                                  00003230
ISN      89       10 G(K)=ZG                                                 00003240
ISN      90          WRITE(NO,11) (G(K),K=1,10)                              00003250
ISN      91          END IF                                                  00003260
ISN      92        3 CONTINUE                                                00003270
ISN      93       99 RETURN                                                  00003280
ISN      94        6 FORMAT(/1H-,10A2,9F8.2,F8.4)                            00003290
ISN      95        7 FORMAT(1H ,13X,'MEAS   ',9F8.2,F8.4)                    00003300
ISN      96        8 FORMAT(1H ,13X,'RESID  ',9F8.2,F8.4)                    00003310
ISN      97        9 FORMAT(1H ,13X,'STAT   ',9F8.2,F8.4)                    00003320
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:36      NAME: ANTAB   PAGE:   40

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN      98       11 FORMAT(1H ,13X,'RATIO X',9F8.2,F8.2)                                  00003330
ISN      99          END                                                                   00003340

*STATISTICS*   SOURCE STATEMENTS = 98, PROGRAM SIZE = 3120 BYTES, PROGRAM NAME = ANTAB     PAGE:   38.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 19 *******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:37      NAME: MAIN     PAGE:   41

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   OOSTMT NOBECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                       C                                                                  00003350
                       C     SUBROUTINE TO CHECK STREAM ENTHALPIES                        00003360
                       C                                                                  00003370
ISN         1                SUBROUTINE ENBAL(NO,NP,H,Z,D,DW)                          00003380
ISN         2                COMMON NL,NO1,NO2,NO3,NP1,NP2,NP3,MMAX                    00003390
ISN         3                DIMENSION Z(1),H(1),D(1),DW(1),ZZ(7),HH(7)                00003400
ISN         4                NO=10                                                     00003410
ISN         5                WRITE(NO,2)                                               00003420
ISN         6              2 FORMAT(1H1)                                               00003430
ISN         7                DO 1 J=1,NP2                                              00003440
ISN         8                HE=0                                                      00003450
ISN         9                DO 3 M=1,NL                                               00003460
ISN        10                CALL LOC(M,J,MJ,NL,NP1,0)                                 00003470
ISN        11                CALL LOC(M,J,NJ,NL,NP2,0)                                 00003480
ISN        12                ZZ(M)=Z(NJ)                                               00003490
ISN        13                HH(M)=H(MJ)                                               00003500
ISN        14              3 HE=HE+ZZ(M)*HH(M)*(D(J)+DW(J))                            00003510
ISN        15                WRITE(NO,4) J,D(J),DW(J),((ZZ(M),HH(M)),M=1,NL),HE        00003520
ISN        16              4 FORMAT(I3,2F8.1,5(F7.4,E11.4),E11.4)                      00003530
ISN        17              1 CONTINUE                                                  00003540
ISN        18                NP4=NP2+1                                                 00003550
ISN        19                DO 5 J=NP4,NP1                                            00003560
ISN        20                CALL LOC(NL,J,MJ,NL,NP1,0)                                00003570
ISN        21                HH(NL)=H(MJ)                                              00003580
ISN        22                HE=HH(NL)*DW(J)                                           00003590
ISN        23                WRITE(NO,6) J,DW(J),HH(NL),HE                             00003600
ISN        24              6 FORMAT(I3,8X,F8.1,2E11.4)                                 00003610
ISN        25              5 CONTINUE                                                  00003620
ISN        26                RETURN                                                    00003630
ISN        27                END                                                       00003640

*STATISTICS*  SOURCE STATEMENTS = 27, PROGRAM SIZE = 1334 BYTES, PROGRAM NAME = ENBAL    PAGE:   41.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 20 ******
```

OPTIONS IN EFFECT: NOLIST NOMAP NOXREF GOSTMT NODECK SOURCE TERM OBJECT FIXED NOTEST
OPTIMIZE(0) LANGLVL(77) NOFIPS FLAG(I) NAME(MAIN) LINECOUNT(60)

```
                *....*...1.....2.....3.....4.....5.....6.....7.*.....8
                C                                                          00003650
                C DETERMINE EQUILIBRIUM TEMPERATURE FROM COHERENT BALANCE  00003660
                C                                                          00003670
ISN         1         SUBROUTINE TEQB(J,T,Z,TEQ)                           00003680
ISN         2         COMMON NL,NQ1,NQ2,NQ3,NP1,NP2,NP3,MMAX               00003690
ISN         3         DIMENSION Z2(1),Z(1)                                 00003691
ISN         4         CALL LOC(1,J,J1,NL,NP2,0)                            00003700
ISN         5         CALL LOC(2,J,J2,NL,NP2,0)                            00003710
ISN         6         CALL LOC(3,J,J3,NL,NP2,0)                            00003720
ISN         7         CALL LOC(4,J,J4,NL,NP2,0)                            00003730
ISN         8         ZB=1-Z(J1)-Z(J2)                                     00003740
ISN         9         ZN=Z(J3)/ZB                                          00003750
ISN        10         ZK=Z(J4)/ZB                                          00003760
ISN        11         TEQ=T                                                00003770
ISN        12       1 XK=Z2(TEQ,ZN)                                        00003780
ISN        13         DX=ZK-XK                                             00003790
ISN        14         DZ=DZ2(TEQ,ZN)                                       00003800
ISN        15         DT=DX/DZ                                             00003810
ISN        16         TEQ=TEQ+DT                                           00003820
ISN        17         IF(ABS(DT/TEQ).GT.1.0E-4) GO TO 1                    00003830
ISN        18         RETURN                                               00003840
ISN        19         END                                                  00003850
```

CORRECTED ON FILE
COMEBAL.FORT(SUBR)

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:38     NAME: MAIN     PAGE:   43

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NOBECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                      OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN       1           SUBROUTINE TEMPPT                                                  00000010
ISN       2           COMMON NL,NO1,NO2,NO3,NP1,NP2,NP3,MMAX                             00000020
ISN       3           COMMON NTYPE(20),NSTYP(50),NBC(50),F(50),R(50),BF(50),BR(50),      00000030
                     1       NODE(20),DSCND(20,10),NSTR(50),DSCST(10,50),AM1(20,50),    00000040
                     2       T(50),P(50),ST(50),SP(50),ZD(3,50),BZ(3,50),NRF(50),       00000050
                     3       NTP(50),NZ(50),A(350),V(350),Z(350),ZM(7),BZM(7),D(50),    00000060
                     4       IP(50),IW(50),IDW(50),ID(50),SDP(50),SW(50),SDD(50),       00000070
                     5       U(1000),W(50),H(350),C(9999),E(110),TH(100),ED(50),NT(7)   00000080
                     6      ,EED,NT(50),EPS,NNT                                         00000090
ISN       4           IPG=0                                                              00000100
ISN       5           LINES=0                                                            00000110
ISN       6           CALL HDG(IPG,LINES)                                                00000120
ISN       7           DO 10, J=1,NP1                                                     00000130
ISN       8           CALL TEQB(J,T(J),Z,TEQ)                                            00000131
ISN       9             IF (NT(J).EQ.0) THEN                                             00000140
ISN      10               WRITE(10,100) J,(DSCST(I,J),I=1,10),T(J),T(J),ST(J),TEQ       00000160
ISN      11             ELSE                                                             00000170
ISN      12               RES=TH(NT(J))-T(J)                                             00000180
ISN      13               RATIO=(ABS(RES)/ST(J))*100                                     00000190
ISN      14               WRITE(10,101) J,(DSCST(I,J),I=1,10),T(J),TH(NT(J)),RES,        00000200
                     1                       ST(J),RATIO,TEQ                            00000210
ISN      15             END IF                                                           00000220
ISN      16             LINES=LINES+1                                                    00000230
ISN      17             IF(LINES.GT.52) CALL HDG(IPG,LINES)                              00000240
ISN      19          10 CONTINUE                                                         00000250
ISN      20         100 FORMAT(1H ,I4,4X,10A2,8X,F7.2,10X,F7.2,26X,F8.3,27X,F7.2)       00000260
ISN      21         101 FORMAT(1H ,I4,4X,10A2,8X,F7.2,10X,F7.2,8X,F7.2,11X,F8.3,        00000270
                       18X,F7.2,12X,F7.2)                                               00000280
ISN      22           RETURN                                                           00000290
ISN      23           END                                                              00000300

*STATISTICS*  SOURCE STATEMENTS = 22, PROGRAM SIZE = 1094 BYTES, PROGRAM NAME = TEMPPT    PAGE:   43.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 22 ******
```

```
LEVEL 1.2.0 (SEPT  82)          US FORTRAN          DATE: 1983 APR 27     TIME: 12:50:39      NAME: MAIN     PAGE:   44

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                    *....*...1.........2.........3.........4.........5.........6.........7.*.......8

                          C                                                                      00000310
                          C                                                                      00000320
                          C                                                                      00000330
                          C                                                                      00000340
ISN         1                 SUBROUTINE HDG(IPG,LINES)                                        00000350
ISN         2                 IPG=IPG+1                                                        00000360
ISN         3                 LINES=0                                                          00000370
ISN         4                 WRITE(10,100)IPG                                                 00000380
ISN         5                 WRITE(10,101)                                                    00000390
ISN         6                 WRITE(10,102)                                                    00000400
ISN         7                 WRITE(10,103)                                                    00000410
ISN         8            100 FORMAT(1H1,'KILBORN (SASKATCHEWAN) LTD.',20X,'POTASH ',          00000420
                             1'CRYSTALLIZER SIMULATION',46X,'PAGE ',I3)                        00000430
ISN         9            101 FORMAT(1HO,52X,'TEMPERATURE ANALYSIS')                           00000440
ISN        10            102 FORMAT(1HO,119X,'TEMPERATURE')                                   00000450
ISN        11            103 FORMAT(1H ,'STREAM  DESCRIPTION',16X,'MEASURED',10X,             00000460
                             1'BALANCE',7X,'RESIDUAL',10X,'STATISTIC',10X,'RATIO',           00000470
                             210X,'EQUILIBRIUM'/)                                            00000480
ISN        12                 RETURN                                                         00000490
ISN        13                 END

*STATISTICS*   SOURCE STATEMENTS = 13, PROGRAM SIZE = 568 BYTES, PROGRAM NAME = HDG     PAGE:   44.

*STATISTICS*   . NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 23 ******
```

```
LEVEL 1.2.0 (SEPT 82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:39     NAME: MAIN     PAGE:   45

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                      OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN       1          SUBROUTINE FLOTAB                                                    00000500
ISN       2          COMMON NL,NQ1,NQ2,NQ3,NP1,NP2,NP3,MMAX                               00000510
ISN       3          COMMON NTYPE(20),NSTYP(50),NBC(50),F(50),R(50),SF(50),SR(50),        00000520
                    1       NODE(20),DSCND(20,10),NSTR(50),DSCST(10,50),AM1(20,50),     00000530
                    2       T(50),P(50),ST(50),SP(50),ZD(3,50),SZ(3,50),NRF(50),        00000540
                    3       NTF(50),NZ(50),A(350),V(350),Z(350),ZM(7),SZM(7),D(50),      00000550
                    4       DP(50),DW(50),DDW(50),DD(50),SDP(50),SW(50),SDD(50),        00000560
                    5       U(1000),W(50),H(350),C(9999),E(110),TH(100),ED(50),HT(7)     00000570
                    6      ,EED,NT(50),EPS,NNT                                          00000580
ISN       4          IPG=0                                                              00000590
ISN       5          LINES=0                                                            00000600
ISN       6          CALL HDG1(IPG,LINES)                                               00000610
ISN       7          DO 10, J=1,NP1                                                     00000620
ISN       8            CALL LOC(1,J,JR,NL,NP2,0)                                        00000630
ISN       9            S=Z(JR)                                                          00000640
ISN      10            ZBAL=Z(JR)                                                       00000650
ISN      11            CALL LOC(2,J,JR,NL,NP2,0)                                        00000660
ISN      12            S=(S+Z(JR))*100                                                  00000670
ISN      13            ZBAL=ZBAL+Z(JR)                                                  00000680
ISN      14            RATIO=0                                                          00000690
ISN      15            RATIO1=0                                                         00000700
ISN      16            RMEAS=100*R(J)                                                   00000710
ISN      17            CALL LOC(3,J,JR,NL,NP2,0)                                        00000720
ISN      18            SGSL=0                                                           00000730
ISN      19            IF (Z(JR).NE.0) THEN                                             00000740
ISN      20              TC=T(J)                                                        00000750
ISN      21              ZN=Z(JR)/(1-ZBAL)                                              00000760
ISN      22              IF(NT(J).NE.0) TC=TH(NT(J))                                    00000770
ISN      24              RBRIN=RB(TC,ZN)                                                00000780
ISN      25              SGSL=1.984 * ZBAL + (1.0 - ZBAL) * RBRIN                       00000790
ISN      26            END IF                                                           00000800
ISN      27            IF (NRF(J).EQ.2) THEN                                          00000810
ISN      28              RES=DW(J)-DDW(J)                                               00000820
ISN      29              IF(SW(J).NE.0) RATIO=(ABS(RES)/SW(J))*100                      00000830
ISN      31              WRITE(10,100) J,(DSCST(I,J),I=1,10),DDW(J),DW(J),RES,          00000840
                    1                 SW(J),RATIO                                      00000850
ISN      32            ELSE IF (NRF(J).EQ.3) THEN                                     00000860
ISN      33              BAL=D(J)+DW(J)                                                 00000870
ISN      34              RES=DP(J)-BAL                                                  00000880
ISN      35              IF(SDP(J).NE.0) RATIO=(ABS(RES)/SDP(J))*100                    00000890
ISN      37              RES1=S-RMEAS                                                   00000900
ISN      38              IF(SR(J).NE.0) RATIO1=(.01*ABS(RES1)/SR(J))*100                00000910
ISN      40              IF(RMEAS.NE.0) WRITE(10,101) J,(DSCST(I,J),I=1,10),DW(J),      00000920
                    1                  DP(J),BAL,RES,SDP(J),RATIO,RMEAS,S,RES1,      00000930
                    2                  SR(J),RATIO1,SGSL                             00000940
ISN      42              IF(RMEAS.EQ.0) WRITE(10,103) J,(DSCST(I,J),I=1,10),DW(J),      00000950
                    1                  DP(J),BAL,RES,SDP(J),RATIO,S,SGSL             00000960
ISN      44            ELSE                                                           00000980
ISN      45              RES=S-RMEAS                                                    00000990
ISN      46              IF(SR(J).NE.0) RATIO=(.01*ABS(RES)/SR(J))*100                  00001000
ISN      48              IF(RMEAS.NE.0) WRITE(10,102) J,(DSCST(I,J),I=1,10),DW(J),      00001010
                    1                  RMEAS,S,RES,SR(J),RATIO,SGSL                  00001020
ISN      50            IF(RMEAS.EQ.0) WRITE(10,104) J,(DSCST(I,J),I=1,10),DW(J),S,SGSL00001040
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:39      NAME: MAIN     PAGE:   44

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

                       C                                                                      00000310
                       C                                                                      00000320
                       C                                                                      00000330
ISN         1              SUBROUTINE HDG(IPG,LINES)                                         00000340
ISN         2              IPG=IPG+1                                                         00000350
ISN         3              LINES=0                                                           00000360
ISN         4              WRITE(10,100)IPG                                                  00000370
ISN         5              WRITE(10,101)                                                     00000380
ISN         6              WRITE(10,102)                                                     00000390
ISN         7              WRITE(10,103)                                                     00000400
ISN         8          100 FORMAT(1H1,'KILBORN (SASKATCHEWAN) LTD.',20X,'POTASH ',          00000410
                          1'CRYSTALLIZER SIMULATION',46X,'PAGE ',I3)                        00000420
ISN         9          101 FORMAT(1HO,52X,'TEMPERATURE ANALYSIS')                          00000430
ISN        10          102 FORMAT(1HO,119X,'TEMPERATURE')                                  00000440
ISN        11          103 FORMAT(1H ,'STREAM  DESCRIPTION',16X,'MEASURED',10X,            00000450
                          1'BALANCE',7X,'RESIDUAL',10X,'STATISTIC',10X,'RATIO',           00000460
                          210X,'EQUILIBRIUM'/)                                            00000470
ISN        12              RETURN                                                          00000480
ISN        13              END                                                             00000490

*STATISTICS*   SOURCE STATEMENTS = 13, PROGRAM SIZE = 568 BYTES, PROGRAM NAME = HDG     PAGE:   44.

*STATISTICS*   . NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 23 *******
```

```
LEVEL 1.2.0 (SEPT 82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:39     NAME: MAIN     PAGE:   45

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                      OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                #....#...1.....2.....3.....4.....5.....6.....7.#.....8

ISN        1          SUBROUTINE FLOTAB                                                    00000500
ISN        2          COMMON NL,NO1,NO2,NO3,NP1,NP2,NP3,MMAX                               00000510
ISN        3          COMMON NTYPE(20),NSTYP(50),NBC(50),F(50),R(50),GF(50),GR(50),        00000520
                     1       NODE(20),DSCND(20,10),NSTR(50),DSCST(10,50),AM1(20,50),      00000530
                     2       T(50),P(50),ST(50),SP(50),ZD(3,50),GZ(3,50),NRF(50),         00000540
                     3       NTP(50),NZ(50),A(350),V(350),Z(350),ZM(7),GZM(7),D(50),      00000550
                     4       DP(50),DW(50),DDW(50),DD(50),SDP(50),SW(50),SDD(50),         00000560
                     5       U(1000),W(50),H(350),C(9999),E(110),TH(100),ED(50),HT(7)     00000570
                     6      ,EED,NT(50),EPS,NNT                                           00000580
ISN        4          IPG=0                                                                00000590
ISN        5          LINES=0                                                              00000600
ISN        6          CALL HDG1(IPG,LINES)                                                 00000610
ISN        7          DO 10, J=1,NP1                                                       00000620
ISN        8            CALL LOC(1,J,JR,NL,NP2,0)                                          00000630
ISN        9            S=Z(JR)                                                            00000640
ISN       10            ZBAL=Z(JR)                                                         00000650
ISN       11            CALL LOC(2,J,JR,NL,NP2,0)                                          00000660
ISN       12            S=(S+Z(JR))*100                                                    00000670
ISN       13            ZBAL=ZBAL+Z(JR)                                                    00000680
ISN       14            RATIO=0                                                            00000690
ISN       15            RATIO1=0                                                           00000700
ISN       16            RMEAS=100*R(J)                                                     00000710
ISN       17            CALL LOC(3,J,JR,NL,NP2,0)                                          00000720
ISN       18            SGSL=0                                                             00000730
ISN       19            IF (Z(JR).NE.0) THEN                                               00000740
ISN       20              TC=T(J)                                                          00000750
ISN       21              ZN=Z(JR)/(1-ZBAL)                                                00000760
ISN       22              IF(NT(J).NE.0) TC=TH(NT(J))                                      00000770
ISN       24              RBRIN=RB(TC,ZN)                                                  00000780
ISN       25              SGSL=1.904 * ZBAL + (1.0 - ZBAL) * RBRIN                         00000790
ISN       26            END IF                                                             00000800
ISN       27            IF (NRF(J).EQ.2) THEN                                            00000810
ISN       28              RES=DW(J)-DDW(J)                                                 00000820
ISN       29              IF(SW(J).NE.0) RATIO=(ABS(RES)/SW(J))*100                        00000830
ISN       31              WRITE(10,100) J,(DSCSI(I,J),I=1,10),DDW(J),DW(J),RES,            00000840
                     1                    SW(J),RATIO                                     00000850
ISN       32            ELSE IF (NRF(J).EQ.3) THEN                                       00000860
ISN       33              BAL=D(J)+DW(J)                                                   00000870
ISN       34              RES=DP(J)-BAL                                                    00000880
ISN       35              IF(SDP(J).NE.0) RATIO=(ABS(RES)/SDP(J))*100                      00000890
ISN       37              RES1=S-RMEAS                                                     00000900
ISN       38              IF(SR(J).NE.0) RATIO1=(.01*ABS(RES1)/SR(J))*100                  00000910
ISN       40              IF(RMEAS.NE.0) WRITE(10,101) J,(DSCST(I,J),I=1,10),DW(J),        00000920
                     1                    DP(J),BAL,RES,SDP(J),RATIO,RMEAS,S,RES1,       00000930
                     2                    SR(J),RATIO1,SGSL                              00000940
ISN       42              IF(RMEAS.EQ.0) WRITE(10,103) J,(DSCST(I,J),I=1,10),DW(J),      00000950
                     1                    DP(J),BAL,RES,SDP(J),RATIO,S,SGSL              00000960
ISN       44            ELSE                                                             00000980
ISN       45              RES=S-RMEAS                                                    00000990
ISN       46              IF(SR(J).NE.0) RATIO=(.01*ABS(RES)/SR(J))*100                  00001000
ISN       48              IF(RMEAS.NE.0) WRITE(10,102) J,(DSCST(I,J),I=1,10),DW(J),      00001010
                     1                    RMEAS,S,RES,SR(J),RATIO,SGSL                   00001020
ISN       50            IF(RMEAS.EQ.0) WRITE(10,104) J,(DSCSI(I,J),I=1,10),DW(J),S,SGSL00001040
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:39      NAME: FLOTAB  PAGE:   46

                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       52            END IF                                                              00001060
ISN       53            LINES=LINES+1                                                       00001070
ISN       54            IF(LINES.GT.52) CALL HDG1(IPG,LINES)                                00001080
ISN       56         10 CONTINUE                                                            00001090
ISN       57        100 FORMAT(1H ,I3,1X,10A2,3(F7.2),F6.2,F7.2)                            00001100
ISN       58        101 FORMAT(1H ,I3,1X,10A2,7X,F7.2,21X,3(F7.2),F6.2,F7.2,1X,3(F6.2),     00001110
                       12PF6.2,0PF7.2,F7.4)                                                00001120
ISN       59        102 FORMAT(1H ,I3,1X,10A2,7X,F7.2,56X,3(F6.2),2PF6.2,0PF7.2,F7.4)       00001130
ISN       60        103 FORMAT(1H ,I3,1X,10A2,7X,F7.2,21X,3(F7.2),F6.2,F7.2,7X,F6.2,        00001140
                      119X,F7.4)                                                           00001150
ISN       61        104 FORMAT(1H ,I3,1X,10A2,7X,F7.2,62X,F6.2,19X,F7.4)                    00001160
ISN       62            RETURN                                                           00001170
ISN       63            END                                                              00001180

*STATISTICS*   SOURCE STATEMENTS = 53, PROGRAM SIZE = 2748 BYTES, PROGRAM NAME = FLOTAB     PAGE:   45.

*STATISTICS*  ---NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 24 *******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:40      NAME: MAIN    PAGE:   47

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                      OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                      C                                                                  00001190
                      C                                                                  00001200
                      C                                                                  00001210
ISN         1             SUBROUTINE HDG1(IPG,LINES)                                   00001220
ISN         2             IPG=IPG+1                                                    00001230
ISN         3             LINES=0                                                      00001240
ISN         4             WRITE(10,100)IPG                                             00001250
ISN         5             WRITE(10,101)                                                00001260
ISN         6             WRITE(10,102)                                                00001270
ISN         7             WRITE(10,103)                                                00001280
ISN         8         100 FORMAT(1H1,'KILBORN (SASKATCHEWAN) LTD.',20X,'POTASH ',      00001290
                        1'CRYSTALLIZER SIMULATION',46X,'PAGE ',I3)                     00001300
ISN         9         101 FORMAT(1HO,55X,'FLOW ANALYSIS')                              00001310
ISN        10         102 FORMAT(1HO,27X,'*..... WATER FLOW .....*',4X,                00001320
                        1'*..... PULP FLOW .....*',3X,'*..... % SOLIDS',               00001330
                        2' .....*')                                                    00001340
ISN        11         103 FORMAT(1H ,'STR DESCRIPTION',8X,                             00001350
                        12(4X,'MEAS    BAL    RES  STAT  RATIO'),3X,                  00001360
                        2'MEAS   BAL   RES  STAT  RATIO  S.G.'/)                       00001370
ISN        12             RETURN                                                       00001380
ISN        13             END                                                          00001390

*STATISTICS*   SOURCE STATEMENTS = 13, PROGRAM SIZE = 652 BYTES, PROGRAM NAME = HDG1     PAGE:   47.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 25 ******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:50:40      NAME: MAIN    PAGE:   48

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*....1.........2.........3.........4.........5.........6.........7.*.......8

ISN        1           FUNCTION X1(T,XMG)                                                  00000010
                 C                                                                         00000020
                 C  NACL SOLUBILITY IN KCL SATURATED BRINE VS TEMP                         00000030
                 C                                                                         00000040
ISN        2           T1=1.8*T+32.                                                        00000050
ISN        3           XG=100*XMG                                                          00000060
ISN        4           IF(T1-160)1,2,2                                                     00000070
ISN        5         1 X1=.01*(23.28-1.128*XG)*EXP((-.001647-.000044*XG)*T1)               00000080
ISN        6           RETURN                                                            00000090
ISN        7         2 X1=.01*(21.56-.777*XG)*EXP((-.001132-.000065*XG)*T1)              00000100
ISN        8           RETURN                                                            00000110
ISN        9           END                                                               00000120

*STATISTICS*  SOURCE STATEMENTS = 9, PROGRAM SIZE = 510 BYTES, PROGRAM NAME = X1    PAGE:   48.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 26 ******
```

XMG - MG LEVEL

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:40      NAME: MAIN     PAGE:   49

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                      OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*....1....+....2....+....3....+....4....+....5....+....6....+....7.*....+....8

                       C                                                                      00000130
                       C                                                                      00000140
                       C                                                                      00000150
ISN        1                FUNCTION DX1(T,XMG)                                              00000160
                       C                                                                      00000170
                       C  PARTIAL DERIVATIVE RE T OF NA SOLUBILITY X1                         00000180
                       C                                                                      00000190
ISN        2                T1=1.8*T+32.                                                     00000200
ISN        3                XG=100.*XMG                                                      00000210
ISN        4                IF(T1-160)1,2,2                                                  00000220
ISN        5              1 DX1=-1.8*X1(T,XMG)*(.001647+.000044*XG)                          00000230
ISN        6                RETURN                                                           00000240
ISN        7              2 DX1=-1.8*X1(T,XMG)*(.001132+.000065*XG)                          00000250
ISN        8                RETURN                                                           00000260
ISN        9                END                                                              00000270

*STATISTICS*   SOURCE STATEMENTS = 9, PROGRAM SIZE = 454 BYTES, PROGRAM NAME = DX1     PAGE:   49.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 27 ******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:50:40      NAME: MAIN    PAGE:   50

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

                       C                                                                    00000280
                       C  KCL SOLUBILITY IN NACL-SATURATED BRINE                            00000290
                       C                                                                    00000300
ISN         1              FUNCTION X2(T,XMG)                                              00000310
ISN         2              T1=1.8*T+32.                                                    00000320
ISN         3              XG=100.*XMG                                                     00000330
ISN         4              IF(T1-160)1,2,2                                                 00000340
ISN         5            1 X2=(4.77-.0834*XG+(.08209-.00250*XG)*T1)*.01                    00000350
ISN         6              RETURN                                                          00000360
ISN         7            2 X2=.01*(5.454+.0367*XG+(.0777-.0028*XG)*T1)                     00000370
ISN         8              RETURN                                                          00000380
ISN         9              END                                                             00000390

*STATISTICS*  SOURCE STATEMENTS = 9, PROGRAM SIZE = 436 BYTES, PROGRAM NAME = X2     PAGE:   50.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 28 *******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:40      NAME: MAIN    PAGE:   51

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                      OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                      C                                                                 00000400
                      C  PARTIAL DERIVATIVE OF X2 RET                                   00000410
                      C                                                                 00000420
ISN         1             FUNCTION DX2(T,XMG)                                         00000430
ISN         2             T1=1.8*T+32.                                                00000440
ISN         3             XG=100.*XMG                                                 00000450
ISN         4             IF(T1-160)1,2,2                                             00000460
ISN         5           1 DX2=.018*(.08209-.00250*XG)                                 00000470
ISN         6             RETURN                                                      00000480
ISN         7           2 DX2=.018*(.0777-.0028*XG)                                   00000490
ISN         8             RETURN                                                      00000500
ISN         9             END                                                         00000510

*STATISTICS*  --SOURCE STATEMENTS =  9,  PROGRAM SIZE =  342 BYTES, PROGRAM NAME = DX2     PAGE:   51.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 29 ******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:40      NAME: MAIN    PAGE:   52

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   OOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

                       C
                       C  VAPOR PRESSURE IN A XLR AS A FUNCTION OF TEMPERATURE                    00000520
                       C                                                                          00000530
                                                                                                  00000540
ISN         1              FUNCTION XLRVP(T,Z1,Z2)                                                00000550
ISN         2              T1=1.8*T+32.                                                           00000560
ISN         3              VPW=.0443551*EXP(.312897282*(T1**.6))                                  00000570
ISN         4              ZW=1.-Z1-Z2                                                            00000580
ISN         5              XW=ZW/18                                                               00000590
ISN         6              XN=Z1/58.46                                                            00000600
ISN         7              XK=Z2/74.56                                                            00000610
ISN         8              XX=XW+XN+XK                                                            00000620
ISN         9              XW=XW/XX                                                               00000630
ISN        10              XN=XN/XX                                                               00000640
ISN        11              XK=XK/XX                                                               00000650
ISN        12              XLRVP=(1.-2.31*(XW+XK))*VPW                                            00000660
ISN        13              RETURN                                                                 00000670
ISN        14              END                                                                    00000680

*STATISTICS*   SOURCE STATEMENTS = 14, PROGRAM SIZE = 530 BYTES, PROGRAM NAME = XLRVP    PAGE:   52.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 30 *******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:41      NAME: MAIN     PAGE:   53

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                      OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*....1....+....2....+....3....+....4....+....5....+....6....+....7.*....+....8

                       C                                                                        00000690
                       C  KCL SOLUBILITY IN BRINE UNDERSATURATED RE NACL                        00000700
                       C                                                                        00000710
ISN         1                FUNCTION Z2(T,Z1)                                                00000720
ISN         2                T1=1.8*T+32.                                                     00000730
ISN         3                ZN=100*Z1                                                        00000740
ISN         4                A=25+.1055*T1                                                    00000750
ISN         5                B=1.0884+.0015*T1                                                00000760
ISN         6                C=1.0246-.00012*T1                                               00000770
ISN         7                IF (A.LE.ZN) THEN                                                00000771
ISN         8                  Z2=ZN                                                          00000772
ISN         9                  GO TO 1                                                        00000773
ISN        10                END IF                                                           00000774
ISN        11                Z2=.01*((A-ZN)/B)**(1/C)                                         00000780
ISN        12              1 RETURN                                                           00000790
ISN        13                END                                                              00000800

*STATISTICS*    SOURCE STATEMENTS = 13, PROGRAM SIZE = 500 BYTES, PROGRAM NAME = Z2     PAGE:   53.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 31 *******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:41      NAME: MAIN    PAGE:   54

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                      C                                                                    00000810
                      C  KCL SOLUBILITY PARTIAL DERIVATIVE RE T                            00000820
                      C                                                                    00000830
ISN         1             FUNCTION DZ2(T,Z1)                                             00000840
ISN         2             T1=.8*T+32.                                                    00000850
ISN         3             ZN=100*Z1                                                      00000860
ISN         4             A=25+.1055*T1                                                  00000870
ISN         5             B=1.0884+.0015*T1                                              00000880
ISN         6             C=1.0884-.00012*T1                                             00000890
ISN         7             U=((A-ZN)/B)                                                   00000900
ISN         8             Z2=.01*(U**(1/C))                                              00000910
ISN         9             DZ2=1.8*Z2*(.1055/(C*U*B)-.0015/(C*B)+.00012*ALOG(U)/(C**2))   00000920
ISN        10             RETURN                                                         00000930
ISN        11             END                                                            00000940

*STATISTICS*    SOURCE STATEMENTS = 11, PROGRAM SIZE = 584 BYTES, PROGRAM NAME = DZ2    PAGE:   54.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

*******-END OF COMPILATION 32-*******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:41      NAME: MAIN     PAGE:   55

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

                      C
                      C  NACL SOLUBILITY IF BRINE UNDERSATURATED RE KCL                    00000950
                      C                                                                    00000960
ISN         1               FUNCTION Z1(T,Z2)                                            00000970
ISN         2               T1=1.8*T+32.                                                 00000980
ISN         3               ZN=100*Z2                                                    00000990
ISN         4               A=.01*(25.6362+.009023*T1)                                   00001000
ISN         5               B=.01*(.591239-.000475*T1)                                   00001010
ISN         6               Z1=A-B*ZN                                                    00001020
ISN         7               RETURN                                                       00001030
ISN         8               END                                                          00001040
                                                                                         00001050

*STATISTICS*   SOURCE STATEMENTS = 8, PROGRAM SIZE = 340 BYTES, PROGRAM NAME = Z1     PAGE:   55.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 33 ******
```

```
LEVEL 1.2.0 (SEPT  92)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:41      NAME: MAIN    PAGE:   56

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

                       C                                                                  00001060
                       C  NACL SOLUBILITY PARTIAL DERIV RE T                              00001070
                       C                                                                  00001080
ISN         1                FUNCTION DZ1(T,Z2)                                        00001090
ISN         2                T1=1.8*T+32.                                              00001100
ISN         3                ZN=100*Z2                                                 00001110
ISN         4                DZ1=.018*(.009023+ZN*.000475)                             00001120
ISN         5                RETURN                                                    00001130
ISN         6                END                                                       00001140

*STATISTICS*   SOURCE STATEMENTS = 6, PROGRAM SIZE = 292 BYTES, PROGRAM NAME = DZ1     PAGE:   56.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 34 ******
```

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LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:41      NAME: MAIN    PAGE:   57

OPTIONS IN EFFECT: NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                   OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *...*...1.........2.........3.........4.........5.........6.........7.*.......8

                       C                                                                  00001150
                       C  SPECIFIC GRAVITY OF WATER VS T.                                 00001160
                       C                                                                  00001170
ISN         1              FUNCTION RW(T)                                                 00001180
ISN         2              IF(T-25)1,2,2                                                  00001190
ISN         3            1 IF(T-4)3,4,3                                                   00001200
ISN         4            4 RW=1.0                                                         00001210
ISN         5              RETURN                                                         00001220
ISN         6            3 RW=1.0008*((ABS(T-4))**(-.00075))                            00001230
ISN         7              RETURN                                                         00001240
ISN         8            2 RW=1.0119*(EXP(-.0005009*T))                                 00001250
ISN         9              RETURN                                                         00001260
ISN        10              END                                                            00001270

*STATISTICS*   SOURCE STATEMENTS = 10, PROGRAM SIZE = 446 BYTES, PROGRAM NAME = RW     PAGE:   57.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 35 ******
```

```
LEVEL 1.2.0 (SEPT 82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:41      NAME: MAIN    PAGE:   58

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

                      C                                                                  00001280
                      C  SPECIFIC GRAVITY OF KCL SATURATED BRINE                         00001290
                      C                                                                  00001300
ISN         1             FUNCTION RB(T,XN)                                            00001310
ISN         2             XK=Z2(T,XN)                                                  00001320
ISN         3             XNS=X1(T,.001)                                               00001330
ISN         4             XKS=X2(T,.001)                                               00001340
ISN         5             XS=XNS/(XNS+XKS)                                             00001350
ISN         6             X=XN/(XN+XK)                                                 00001360
ISN         7             RB=1.2315+1.125E-4*T-.09755*(XS-X)                           00001370
ISN         8             RETURN                                                       00001380
ISN         9             END                                                          00001390

*STATISTICS*  SOURCE STATEMENTS = 9, PROGRAM SIZE = 452 BYTES, PROGRAM NAME = RB     PAGE:   59.

*STATISTICS*  NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 36 *******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:41      NAME: MAIN     PAGE:   59

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.........2.........3.........4.........5.........6.........7.*.......8

                       C                                                                    00001400
                       C  ENTHALPY OF SUPERHEATED STEAM                                     00001410
                       C                                                                    00001420
ISN          1               FUNCTION HSTM(T,P)                                            00001430
ISN          2               T1=1.8*T+32.                                                  00001440
ISN          3               P1=P/6.8948                                                   00001450
ISN          4               HSTM=2.32*((1062.2-.723*P1)+(.4430+.001691*P1)*T1)            00001460
ISN          5               RETURN                                                        00001470
ISN          6               END                                                           00001480

*STATISTICS*   SOURCE STATEMENTS = 6, PROGRAM SIZE = 318 BYTES, PROGRAM NAME = HSTM     PAGE:   59.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 37 ******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27      TIME: 12:58:41       NAME: MAIN     PAGE:   60

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   OSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 #....#...1.....2.....3.....4.....5.....6.....7.#.....8

                      C                                                                  00000010
                      C  ................................................................00000020
                      C                                                                  00000030
                      C        SUBROUTINE MPRD                                           00000040
                      C                                                                  00000050
                      C        PURPOSE                                                   00000060
                      C           MULTIPLY TWO MATRICES TO FORM A RESULTANT MATRIX        00000070
                      C                                                                  00000080
                      C        USAGE                                                     00000090
                      C           CALL MPRD(A,B,R,N,M,MSA,MSB,L)                         00000100
                      C                                                                  00000110
                      C        DESCRIPTION OF PARAMETERS                                 00000120
                      C           A - NAME OF FIRST INPUT MATRIX                         00000130
                      C           B - NAME OF SECOND INPUT MATRIX                        00000140
                      C           R - NAME OF OUTPUT MATRIX                              00000150
                      C           N - NUMBER OF ROWS IN A AND R                          00000160
                      C           M - NUMBER OF COLUMNS IN A AND ROWS IN B               00000170
                      C           MSA - ONE DIGIT NUMBER FOR STORAGE MODE OF MATRIX A    00000180
                      C                 0 - GENERAL                                      00000190
                      C                 1 - SYMMETRIC                                    00000200
                      C                 2 - DIAGONAL                                     00000210
                      C           MSB - SAME AS MSA EXCEPT FOR MATRIX B                  00000220
                      C           L - NUMBER OF COLUMNS IN B AND R                       00000230
                      C                                                                  00000240
                      C        REMARKS                                                   00000250
                      C           MATRIX R CANNOT BE IN THE SAME LOCATION AS MATRICES A OR B 00000260
                      C           NUMBER OF COLUMNS OF MATRIX A MUST BE EQUAL TO NUMBER OF ROW00000270
                      C           OF MATRIX B                                            00000280
                      C                                                                  00000290
                      C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED             00000300
                      C           LOC                                                    00000310
                      C                                                                  00000320
                      C        METHOD                                                    00000330
                      C           THE M BY L MATRIX B IS PREMULTIPLIED BY THE N BY M MATRIX A 00000340
                      C           AND THE RESULT IS STORED IN THE N BY L MATRIX R. THIS IS A 00000350
                      C           ROW INTO COLUMN PRODUCT.                               00000360
                      C           THE FOLLOWING TABLE SHOWS THE STORAGE MODE OF THE OUTPUT 00000370
                      C           MATRIX FOR ALL COMBINATIONS OF INPUT MATRICES          00000380
                      C                        A             B             R             00000390
                      C                     GENERAL       GENERAL       GENERAL          00000400
                      C                     GENERAL       SYMMETRIC     GENERAL          00000410
                      C                     GENERAL       DIAGONAL      GENERAL          00000420
                      C                     SYMMETRIC     GENERAL       GENERAL          00000430
                      C                     SYMMETRIC     SYMMETRIC     GENERAL          00000440
                      C                     SYMMETRIC     DIAGONAL      GENERAL          00000450
                      C                     DIAGONAL      GENERAL       GENERAL          00000460
                      C                     DIAGONAL      SYMMETRIC     GENERAL          00000470
                      C                     DIAGONAL      DIAGONAL      DIAGONAL         00000480
                      C                                                                  00000490
                      C  ................................................................00000500
                      C                                                                  00000510
ISN        1          SUBROUTINE MPRD(A,B,R,N,M,MSA,MSB,L)                               00000520
ISN        2          DIMENSION A(1),B(1),R(1)                                           00000530
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:41       NAME: MPRD     PAGE:   61

                *....*...1.........2.........3.........4.........5.........6.........7.*........8

                C                                                                              00000540
                C       SPECIAL CASE FOR DIAGONAL BY DIAGONAL                                  00000550
                C                                                                              00000560
ISN         3       MB=MSA*10+MSB                                                              00000570
ISN         4       IF(MB-22) 30,10,30                                                         00000580
ISN         5    10 DO 20 I=1,N                                                                00000590
ISN         6    20 R(I)=A(I)*B(I)                                                             00000600
ISN         7       RETURN                                                                     00000610
                C                                                                              00000620
                C       ALL OTHER CASES                                                        00000630
                C                                                                              00000640
ISN         8    30 IR=1                                                                       00000650
ISN         9       DO 90 K=1,L                                                                00000660
ISN        10       DO 90 J=1,N                                                                00000670
ISN        11       R(IR)=0                                                                    00000680
ISN        12       DO 80 I=1,M                                                                00000690
ISN        13       IF(MB) 40,60,40                                                            00000700
ISN        14    40 CALL LOC(J,I,IA,N,M,MSA)                                                   00000710
ISN        15       CALL LOC(I,K,IB,M,L,MSB)                                                   00000720
ISN        16       IF(IA) 50,80,50                                                            00000730
ISN        17    50 IF(IB) 70,80,70                                                            00000740
ISN        18    60 IA=N*(I-1)+J                                                               00000750
ISN        19       IB=M*(K-1)+I                                                               00000760
ISN        20    70 R(IR)=R(IR)+A(IA)*B(IB)                                                    00000770
ISN        21    80 CONTINUE                                                                   00000780
ISN        22    90 IR=IR+1                                                                    00000790
ISN        23       RETURN                                                                     00000800
ISN        24       END                                                                        00000810

*STATISTICS*   SOURCE STATEMENTS = 24, PROGRAM SIZE = 1090 BYTES, PROGRAM NAME = MPRD     PAGE:   60.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 38 ******
```

OPTIONS IN EFFECT: NOLIST NOMAP NOXREF GOSTMT NOPECK SOURCE TERM OBJECT FIXED NOTEST
OPTIMIZE(0) LANGLVL(77) NOFIPS FLAG(I) NAME(MAIN) LINECOUNT(60)

```
*....*...1.....2.....3.....4.....5.....6.....7.*.....8
C                                                                       LOC   10
C  .....LOC   20
C                                                                       LOC   30
C     SUBROUTINE LOC                                                    LOC   40
C                                                                       LOC   50
C     PURPOSE                                                           LOC   60
C        COMPUTE A VECTOR SUBSCRIPT FOR AN ELEMENT IN A MATRIX OF       LOC   70
C        SPECIFIED STORAGE MODE                                         LOC   80
C                                                                       LOC   90
C     USAGE                                                             LOC  100
C        CALL LOC (I,J,IR,N,M,MS)                                       LOC  110
C                                                                       LOC  120
C     DESCRIPTION OF PARAMETERS                                         LOC  130
C        I  - ROW NUMBER OF ELEMENT                                     LOC  140
C        J  - COLUMN NUMBER  OF ELEMENT                                 LOC  150
C        IR - RESULTANT VECTOR SUBSCRIPT                                LOC  160
C        N  - NUMBER OF ROWS IN MATRIX                                  LOC  170
C        M  - NUMBER OF COLUMNS IN MATRIX                               LOC  180
C        MS - ONE DIGIT NUMBER FOR STORAGE MODE OF MATRIX               LOC  190
C             0 - GENERAL                                               LOC  200
C             1 - SYMMETRIC                                             LOC  210
C             2 - DIAGONAL                                              LOC  220
C                                                                       LOC  230
C     REMARKS                                                           LOC  240
C        NONE                                                           LOC  250
C  .....LOC  260
C     SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                     LOC  270
C        NONE                                                           LOC  280
C                                                                       LOC  290
C     METHOD                                                            LOC  300
C        MS=0   SUBSCRIPT IS COMPUTED FOR A MATRIX WITH N*M ELEMENTS    LOC  310
C               IN STORAGE (GENERAL MATRIX).                            LOC  320
C        MS=1   SUBSCRIPT IS COMPUTED FOR A MATRIX WITH N*(N+1)/2 IN    LOC  330
C               STORAGE (UPPER TRIANGLE OF SYMMETRIC MATRIX). IF        LOC  340
C               ELEMENT IS IN LOWER TRIANGULAR PORTION, SUBSCRIPT IS    LOC  350
C               CORRESPONDING ELEMENT IN UPPER TRIANGLE.                LOC  360
C        MS=2   SUBSCRIPT IS COMPUTED FOR A MATRIX WITH N ELEMENTS      LOC  370
C               IN STORAGE (DIAGONAL ELEMENTS OF DIAGONAL MATRIX).      LOC  380
C               IF ELEMENT IS NOT ON DIAGONAL (AND THEREFORE NOT IN     LOC  390
C               STORAGE), IR IS SET TO ZERO.                            LOC  400
C                                                                       LOC  410
C  .....LOC  420
C                                                                       LOC  430
ISN    1        SUBROUTINE LOC(I,J,IR,N,M,MS)                          LOC  440
C                                                                       LOC  450
ISN    2           IX=I                                                LOC  460
ISN    3           JX=J                                                LOC  470
ISN    4           IF(MS-1) 10,20,30                                   LOC  480
ISN    5        10 IRX=N*(JX-1)+IX                                     LOC  490
ISN    6           GO TO 36                                            LOC  500
ISN    7        20 IF(IX-JX) 22,24,24                                  LOC  510
ISN    8        22 IRX=IX+(JX*JX-JX)/2                                 LOC  520
ISN    9           GO TO 36                                            LOC  530
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:42      NAME: LOC      PAGE:   65

                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

ISN       10       24 IRX=JX+(IX*IX-IX)/2                                                  LOC  540
ISN       11          GO TO 36                                                             LOC  550
ISN       12       30 IRX=0                                                                LOC  560
ISN       13          IF(IX-JX) 36,32,36                                                   LOC  570
ISN       14       32 IRX=IX                                                               LOC  580
ISN       15       36 IR=IRX                                                               LOC  590
ISN       16          RETURN                                                               LOC  600
ISN       17          END                                                                  LOC  610

*STATISTICS*   SOURCE STATEMENTS = 17, PROGRAM SIZE = 480 BYTES, PROGRAM NAME = LOC     PAGE:   64.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

****** END OF COMPILATION 40 ******
```

```
LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:43      NAME: MAIN    PAGE:   66

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                    OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8
                 C                                                                      00000010
                 C  ....................................................................00000020
                 C                                                                      00000030
                 C        SUBROUTINE GELG                                               00000040
                 C                                                                      00000050
                 C        PURPOSE                                                       00000060
                 C           TO SOLVE A GENERAL SYSTEM OF SIMULTANEOUS LINEAR EQUATIONS. 00000070
                 C                                                                      00000080
                 C        USAGE                                                         00000090
                 C           CALL GELG(R,A,M,N,EPS,IER)                                 00000100
                 C                                                                      00000110
                 C        DESCRIPTION OF PARAMETERS                                     00000120
                 C           R      - THE M BY N MATRIX OF RIGHT HAND SIDES.  (DESTROYED)00000130
                 C                    ON RETURN R CONTAINS THE SOLUTION OF THE EQUATIONS.00000140
                 C           A      - THE M BY M COEFFICIENT MATRIX.  (DESTROYED)       00000150
                 C           M      - THE NUMBER OF EQUATIONS IN THE SYSTEM.            00000160
                 C           N      - THE NUMBER OF RIGHT HAND SIDE VECTORS.            00000170
                 C           EPS    - AN INPUT CONSTANT WHICH IS USED AS RELATIVE       00000180
                 C                    TOLERANCE FOR TEST ON LOSS OF SIGNIFICANCE.       00000190
                 C           IER    - RESULTING ERROR PARAMETER CODED AS FOLLOWS:       00000200
                 C                    IER=0  - NO ERROR,                                00000210
                 C                    IER=-1 - NO RESULT BECAUSE OF M LESS THAN 1 OR    00000220
                 C                             PIVOT ELEMENT AT ANY ELIMINATION STEP    00000230
                 C                             EQUAL TO 0,                              00000240
                 C                    IER=K  - WARNING DUE TO POSSIBLE LOSS OF SIGNIFI- 00000250
                 C                             CANCE INDICATED AT ELIMINATION STEP K+1, 00000260
                 C                             WHERE PIVOT ELEMENT WAS LESS THAN OR     00000270
                 C                             EQUAL TO THE INTERNAL TOLERANCE EPS TIMES00000280
                 C                             ABSOLUTELY GREATEST ELEMENT OF MATRIX A. 00000290
                 C                                                                      00000300
                 C        REMARKS                                                       00000310
                 C           INPUT MATRICES R AND A ARE ASSUMED TO BE STORED COLUMNWISE 00000320
                 C           IN M*N RESP. M*M SUCCESSIVE STORAGE LOCATIONS. ON RETURN  00000330
                 C           SOLUTION MATRIX R IS STORED COLUMNWISE TOO.               00000340
                 C           THE PROCEDURE GIVES RESULTS IF THE NUMBER OF EQUATIONS M IS00000350
                 C           GREATER THAN 0 AND PIVOT ELEMENTS AT ALL ELIMINATION STEPS 00000360
                 C           ARE DIFFERENT FROM 0. HOWEVER WARNING IER=K - IF GIVEN -  00000370
                 C           INDICATES POSSIBLE LOSS OF SIGNIFICANCE. IN CASE OF A WELL00000380
                 C           SCALED MATRIX A AND APPROPRIATE TOLERANCE EPS, IER=K MAY BE00000390
                 C           INTERPRETED THAT MATRIX A HAS THE RANK K. NO WARNING IS    00000400
                 C           GIVEN IN CASE M=1.                                        00000410
                 C                                                                      00000420
                 C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                 00000430
                 C           NONE                                                       00000440
                 C                                                                      00000450
                 C        METHOD                                                        00000460
                 C           SOLUTION IS DONE BY MEANS OF GAUSS-ELIMINATION WITH       00000470
                 C           COMPLETE PIVOTING.                                        00000480
                 C                                                                      00000490
                 C  ....................................................................00000500
                 C                                                                      00000510
ISN        1        SUBROUTINE GELG(R,A,M,N,EPS,IER)                                   00000520
                 C                                                                      00000530
```

```
                *....*...1.....2.....3.....4.....5.....6.....7.*.....8
                C
ISN        2          DIMENSION A(1),R(1)                                  00000540
ISN        3          IF(M)23,23,1                                         00000550
                C                                                          00000560
                C     SEARCH FOR GREATEST ELEMENT IN MATRIX A              00000570
ISN        4        1 IER=0                                                00000580
ISN        5          PIV=0.                                               00000590
ISN        6          MM=M*M                                               00000600
ISN        7          NM=N*M                                               00000610
ISN        8          DO 3 L=1,MM                                          00000620
ISN        9          TB=ABS(A(L))                                         00000630
ISN       10          IF(TB-PIV)3,3,2                                      00000640
ISN       11        2 PIV=TB                                               00000650
ISN       12          I=L                                                  00000660
ISN       13        3 CONTINUE                                             00000670
ISN       14          TOL=EPS*PIV                                          00000680
                C     A(I) IS PIVOT ELEMENT, PIV CONTAINS THE ABSOLUTE VALUE OF A(I)  00000690
                C                                                          00000700
                C                                                          00000710
                C     START ELIMINATION LOOP                               00000720
ISN       15          LST=1                                                00000730
ISN       16          DO 17 K=1,M                                          00000740
                C                                                          00000750
                C     TEST ON SINGULARITY                                  00000760
ISN       17          IF(PIV)23,23,4                                       00000770
ISN       18        4 IF(IER)7,5,7                                         00000780
ISN       19        5 IF(PIV-TOL)6,6,7                                     00000790
ISN       20        6 IER=K-1                                              00000800
ISN       21        7 PIVI=1./A(I)                                         00000810
ISN       22          J=(I-1)/M                                            00000820
ISN       23          I=I-J*M-K                                            00000830
ISN       24          J=J+1-K                                              00000840
                C     I+K IS ROW-INDEX, J+K COLUMN-INDEX OF PIVOT ELEMENT  00000850
                C                                                          00000860
                C     PIVOT ROW REDUCTION AND ROW INTERCHANGE IN RIGHT HAND SIDE R  00000870
ISN       25          DO 8 L=K,NM,M                                        00000880
ISN       26          LL=L+I                                               00000890
ISN       27          TB=PIVI*R(LL)                                        00000900
ISN       28          R(LL)=R(L)                                           00000910
ISN       29        8 R(L)=TB                                              00000920
                C                                                          00000930
                C     IS ELIMINATION TERMINATED                            00000940
ISN       30          IF(K-M)9,18,18                                       00000950
                C                                                          00000960
                C     COLUMN INTERCHANGE IN MATRIX A                       00000970
ISN       31        9 LEND=LST+M-K                                         00000980
ISN       32          IF(J)12,12,10                                        00000990
ISN       33       10 II=J*M                                               00001000
ISN       34          DO 11 L=LST,LEND                                     00001010
ISN       35          TB=A(L)                                              00001020
ISN       36          LL=L+II                                              00001030
ISN       37          A(L)=A(LL)                                           00001040
ISN       38       11 A(LL)=TB                                             00001050
                C                                                          00001060
                C     ROW INTERCHANGE AND PIVOT ROW REDUCTION IN MATRIX A  00001070
ISN       39       12 DO 13 L=LST,MM,M                                     00001080
                                                                           00001090
```

```
      *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN       40         LL=L+I                                          00001100
ISN       41         TB=PIVI*A(LL)                                   00001110
ISN       42         A(LL)=A(L)                                      00001120
ISN       43      13 A(L)=TB                                         00001130
                C                                                   00001140
                C     SAVE COLUMN INTERCHANGE INFORMATION           00001150
ISN       44         A(LST)=J                                        00001160
                C                                                   00001170
                C     ELEMENT REDUCTION AND NEXT PIVOT SEARCH       00001180
ISN       45         PIV=0.                                          00001190
ISN       46         LST=LST+1                                       00001200
ISN       47         J=0                                             00001210
ISN       48         DO 16 II=LST,LEND                               00001220
ISN       49         PIVI=-A(II)                                     00001230
ISN       50         IST=II+M                                        00001240
ISN       51         J=J+1                                           00001250
ISN       52         DO 15 L=IST,MM,M                                00001260
ISN       53         LL=L-J                                          00001270
ISN       54         A(L)=A(L)+PIVI*A(LL)                            00001280
ISN       55         TB=ABS(A(L))                                    00001290
ISN       56         IF(TB-PIV)15,15,14                              00001300
ISN       57      14 PIV=TB                                          00001310
ISN       58         I=L                                             00001320
ISN       59      15 CONTINUE                                        00001330
ISN       60         DO 16 L=K,NM,M                                  00001340
ISN       61         LL=L+J                                          00001350
ISN       62      16 R(LL)=R(LL)+PIVI*R(L)                           00001360
ISN       63      17 LST=LST+M                                       00001370
                C     END OF ELIMINATION LOOP                       00001380
                C                                                   00001390
                C                                                   00001400
                C     BACK SUBSTITUTION AND BACK INTERCHANGE        00001410
ISN       64      18 IF(M-1)23,22,19                                 00001420
ISN       65      19 IST=MM+M                                        00001430
ISN       66         LST=M+1                                         00001440
ISN       67         DO 21 I=2,M                                     00001450
ISN       68         II=LST-I                                        00001460
ISN       69         IST=IST-LST                                     00001470
ISN       70         L=IST-M                                         00001480
ISN       71         L=A(L)+.5                                       00001490
ISN       72         DO 21 J=II,NM,M                                 00001500
ISN       73         TB=R(J)                                         00001510
ISN       74         LL=J                                            00001520
ISN       75         DO 20 K=IST,MM,M                                00001530
ISN       76         LL=LL+1                                         00001540
ISN       77      20 TB=TB-A(K)*R(LL)                                00001550
ISN       78         K=J+L                                           00001560
ISN       79         R(J)=R(K)                                       00001570
ISN       80      21 R(K)=TB                                         00001580
ISN       81      22 RETURN                                          00001590
                C                                                   00001600
                C                                                   00001610
                C     ERROR RETURN                                  00001620
ISN       82      23 IER=-1                                          00001630
ISN       83         RETURN                                          00001640
ISN       84         END                                             00001650
```

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LEVEL 1.2.0 (SEPT  82)          VS FORTRAN          DATE: 1983 APR 27     TIME: 12:58:44      NAME: MAIN    PAGE:   70

OPTIONS IN EFFECT:  NOLIST NOMAP NOXREF   GOSTMT NODECK   SOURCE   TERM   OBJECT FIXED  NOTEST
                      OPTIMIZE(0)  LANGLVL(77) NOFIPS   FLAG(I)  NAME(MAIN  )  LINECOUNT(60)

                *....*...1.....2.....3.....4.....5.....6.....7.*.....8
                C                                                                      00000010
                C  ....................................................................00000020
                C                                                                      00000030
                C       SUBROUTINE GELS                                                00000040
                C                                                                      00000050
                C       PURPOSE                                                        00000060
                C          TO SOLVE A SYSTEM OF SIMULTANEOUS LINEAR EQUATIONS WITH     00000070
                C          SYMMETRIC COEFFICIENT MATRIX UPPER TRIANGULAR PART OF WHICH 00000080
                C          IS ASSUMED TO BE STORED COLUMNWISE.                         00000090
                C                                                                      00000100
                C       USAGE                                                          00000110
                C          CALL GELS(R,A,M,N,EPS,IER,AUX)                              00000120
                C                                                                      00000130
                C       DESCRIPTION OF PARAMETERS                                      00000140
                C          R      - M BY N RIGHT HAND SIDE MATRIX.  (DESTROYED)        00000150
                C                   ON RETURN R CONTAINS THE SOLUTION OF THE EQUATIONS.00000160
                C          A      - UPPER TRIANGULAR PART OF THE SYMMETRIC             00000170
                C                   M BY M COEFFICIENT MATRIX.  (DESTROYED)           00000180
                C          M      - THE NUMBER OF EQUATIONS IN THE SYSTEM.             00000190
                C          N      - THE NUMBER OF RIGHT HAND SIDE VECTORS.             00000200
                C          EPS    - AN INPUT CONSTANT WHICH IS USED AS RELATIVE        00000210
                C                   TOLERANCE FOR TEST ON LOSS OF SIGNIFICANCE.       00000220
                C          IER    - RESULTING ERROR PARAMETER CODED AS FOLLOWS         00000230
                C                   IER=0  - NO ERROR,                                00000240
                C                   IER=-1 - NO RESULT BECAUSE OF M LESS THAN 1 OR    00000250
                C                            PIVOT ELEMENT AT ANY ELIMINATION STEP    00000260
                C                            EQUAL TO 0,                              00000270
                C                   IER=K  - WARNING DUE TO POSSIBLE LOSS OF SIGNIFI- 00000280
                C                            CANCE INDICATED AT ELIMINATION STEP K+1, 00000290
                C                            WHERE PIVOT ELEMENT WAS LESS THAN OR     00000300
                C                            EQUAL TO THE INTERNAL TOLERANCE EPS TIMES 00000310
                C                            ABSOLUTELY GREATEST MAIN DIAGONAL        00000320
                C                            ELEMENT OF MATRIX A.                     00000330
                C          AUX    - AN AUXILIARY STORAGE ARRAY WITH DIMENSION M-1.     00000340
                C                                                                      00000350
                C       REMARKS                                                        00000360
                C          UPPER TRIANGULAR PART OF MATRIX A IS ASSUMED TO BE STORED   00000370
                C          COLUMNWISE IN M*(M+1)/2 SUCCESSIVE STORAGE LOCATIONS, RIGHT 00000380
                C          HAND SIDE MATRIX R COLUMNWISE IN N*M SUCCESSIVE STORAGE     00000390
                C          LOCATIONS. ON RETURN SOLUTION MATRIX R IS STORED COLUMNWISE 00000400
                C          TOO.                                                        00000410
                C          THE PROCEDURE GIVES RESULTS IF THE NUMBER OF EQUATIONS M IS 00000420
                C          GREATER THAN 0 AND PIVOT ELEMENTS AT ALL ELIMINATION STEPS  00000430
                C          ARE DIFFERENT FROM 0. HOWEVER WARNING IER=K - IF GIVEN -    00000440
                C          INDICATES POSSIBLE LOSS OF SIGNIFICANCE. IN CASE OF A WELL  00000450
                C          SCALED MATRIX A AND APPROPRIATE TOLERANCE EPS, IER=K MAY BE  00000460
                C          INTERPRETED THAT MATRIX A HAS THE RANK K. NO WARNING IS     00000470
                C          GIVEN IN CASE M=1.                                          00000480
                C          ERROR PARAMETER IER=-1 DOES NOT NECESSARILY MEAN THAT       00000490
                C          MATRIX A IS SINGULAR, AS ONLY MAIN DIAGONAL ELEMENTS        00000500
                C          ARE USED AS PIVOT ELEMENTS. POSSIBLY SUBROUTINE GELG (WHICH 00000510
                C          WORKS WITH TOTAL PIVOTING) WOULD BE ABLE TO FIND A SOLUTION.00000520
                C                                                                      00000530
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                *....*...1.........2.........3.........4.........5.........6.........7.*.......8

                C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                        00000540
                C           NONE                                                              00000550
                C                                                                             00000560
                C        METHOD                                                               00000570
                C           SOLUTION IS DONE BY MEANS OF GAUSS-ELIMINATION WITH               00000580
                C           PIVOTING IN MAIN DIAGONAL, IN ORDER TO PRESERVE                   00000590
                C           SYMMETRY IN REMAINING COEFFICIENT MATRICES.                       00000600
                C                                                                             00000610
                C  ...........................................................................00000620
                C                                                                             00000630
ISN         1       SUBROUTINE GELS(R,A,M,N,EPS,IER,AUX)                                      00000640
                C                                                                             00000650
                C                                                                             00000660
ISN         2          DIMENSION A(1),R(1),AUX(1)                                             00000670
ISN         3          IF(M)24,24,1                                                           00000680
                C                                                                             00000690
                C     SEARCH FOR GREATEST MAIN DIAGONAL ELEMENT                               00000700
ISN         4        1 IER=0                                                                  00000710
ISN         5          PIV=0.                                                                 00000720
ISN         6          L=0                                                                    00000730
ISN         7          DO 3 K=1,M                                                             00000740
ISN         8          L=L+K                                                                  00000750
ISN         9          TB=ABS(A(L))                                                           00000760
ISN        10          IF(TB-PIV)3,3,2                                                        00000770
ISN        11        2 PIV=TB                                                                 00000780
ISN        12          I=L                                                                    00000790
ISN        13          J=K                                                                    00000800
ISN        14        3 CONTINUE                                                               00000810
ISN        15          TOL=EPS*PIV                                                            00000820
                C     MAIN DIAGONAL ELEMENT A(I)=A(J,J) IS FIRST PIVOT ELEMENT.               00000830
                C     PIV CONTAINS THE ABSOLUTE VALUE OF A(I).                                00000840
                C                                                                             00000850
                C                                                                             00000860
                C     START ELIMINATION LOOP                                                  00000870
ISN        16          LST=0                                                                  00000880
ISN        17          NM=N*M                                                                 00000890
ISN        18          LEND=M-1                                                               00000900
ISN        19          DO 18 K=1,M                                                            00000910
                C                                                                             00000920
                C     TEST ON USEFULNESS OF SYMMETRIC ALGORITHM                               00000930
ISN        20          IF(PIV)24,24,4                                                         00000940
ISN        21        4 IF(IER)7,5,7                                                           00000950
ISN        22        5 IF(PIV-TOL)6,6,7                                                       00000960
ISN        23        6 IER=K-1                                                                00000970
ISN        24        7 LT=J-K                                                                 00000980
ISN        25          LST=LST+K                                                              00000990
                C                                                                             00001000
                C     PIVOT ROW REDUCTION AND ROW INTERCHANGE IN RIGHT HAND SIDE R             00001010
ISN        26          PIVI=1./A(I)                                                           00001020
ISN        27          DO 8 L=K,NM,M                                                          00001030
ISN        28          LL=L+LT                                                                00001040
ISN        29          TB=PIVI*R(LL)                                                          00001050
ISN        30          R(LL)=R(L)                                                             00001060
ISN        31        8 R(L)=TB                                                                00001070
                C                                                                             00001080
                C     IS ELIMINATION TERMINATED                                               00001090
```

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                *....*...1.....2.....3.....4.....5.....6.....7.*.....8
ISN       32        IF(K-M)9,19,19                                          00001100
                C                                                           00001110
                C     ROW AND COLUMN INTERCHANGE AND PIVOT ROW REDUCTION IN MATRIX A.  00001120
                C     ELEMENTS OF PIVOT COLUMN ARE SAVED IN AUXILIARY VECTOR AUX.     00001130
                                                                            00001140
ISN       33      9 LR=LST+(LT*(K+J-1))/2                                   00001150
ISN       34        LL=LR                                                   00001160
ISN       35        L=LST                                                   00001170
ISN       36        DO 14 II=K,LEND                                         00001180
ISN       37        L=L+II                                                  00001190
ISN       38        LL=LL+1                                                 00001200
ISN       39        IF(L-LR)12,10,11                                        00001210
ISN       40     10 A(LL)=A(LST)                                            00001220
ISN       41        TB=A(L)                                                 00001230
ISN       42        GO TO 13                                                00001240
ISN       43     11 LL=L+LT                                                 00001250
ISN       44     12 TB=A(LL)                                                00001260
ISN       45        A(LL)=A(L)                                              00001270
ISN       46     13 AUX(II)=TB                                              00001280
ISN       47     14 A(L)=PIVI*TB                                            00001290
                C                                                           00001300
                C     SAVE COLUMN INTERCHANGE INFORMATION                   00001310
ISN       48        A(LST)=LT                                               00001320
                C                                                           00001330
                C     ELEMENT REDUCTION AND SEARCH FOR NEXT PIVOT           00001340
ISN       49        PIV=0.                                                  00001350
ISN       50        LLST=LST                                                00001360
ISN       51        LT=0                                                    00001370
ISN       52        DO 18 II=K,LEND                                         00001380
ISN       53        PIVI=-AUX(II)                                           00001390
ISN       54        LL=LLST                                                 00001400
ISN       55        LT=LT+1                                                 00001410
ISN       56        DO 15 LLD=II,LEND                                       00001420
ISN       57        LL=LL+LLD                                               00001430
ISN       58        L=LL+LT                                                 00001440
ISN       59     15 A(L)=A(L)+PIVI*A(LL)                                    00001450
ISN       60        LLST=LLST+II                                            00001460
ISN       61        LR=LLST+LT                                              00001470
ISN       62        TB=ABS(A(LR))                                           00001480
ISN       63        IF(TB-PIV)17,17,16                                      00001490
ISN       64     16 PIV=TB                                                  00001500
ISN       65        I=LR                                                    00001510
ISN       66        J=II+1                                                  00001520
ISN       67     17 DO 18 LR=K,NN,M                                         00001530
ISN       68        LL=LR+LT                                                00001540
ISN       69     18 R(LL)=R(LL)+PIVI*R(LR)                                  00001550
                C     END OF ELIMINATION LOOP                               00001560
                                                                            00001570
                C                                                           00001580
                C     BACK SUBSTITUTION AND BACK INTERCHANGE                00001590
ISN       70     19 IF(LEND)24,23,20                                        00001600
ISN       71     20 II=M                                                    00001610
ISN       72        DO 22 I=2,M                                             00001620
ISN       73        LST=LST-II                                              00001630
ISN       74        II=II-1                                                 00001640
ISN       75        L=A(LST)+.5                                             00001650
ISN       76        DO 22 J=II,NN,M                                         00001660
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                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8

ISN         77          TB=R(J)                                                    00001660
ISN         78          LL=J                                                       00001670
ISN         79          K=LST                                                      00001680
ISN         80          DO 21 LT=II,LEND                                           00001690
ISN         81          LL=LL+1                                                    00001700
ISN         82          K=K+LT                                                     00001710
ISN         83       21 TB=TB-A(K)*R(LL)                                           00001720
ISN         84          K=J+L                                                      00001730
ISN         85          R(J)=R(K)                                                  00001740
ISN         86       22 R(K)=TB                                                    00001750
ISN         87       23 RETURN                                                     00001760
                    C                                                            00001770
                    C                                                            00001780
                    C     ERROR RETURN                                           00001790
ISN         88       24 IER=-1                                                     00001800
ISN         89          RETURN                                                     00001810
ISN         90          END                                                        00001820

*STATISTICS*   SOURCE STATEMENTS = 90, PROGRAM SIZE = 2710 BYTES, PROGRAM NAME = GELS     PAGE:   70.

*STATISTICS*    NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 43 *******
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OPTIONS IN EFFECT: NOLIST NOMAP NOXREF GOSTMT NODECK SOURCE TERM OBJECT FIXED NOTEST
OPTIMIZE(0) LANGLVL(77) NOFIPS FLAG(I) NAME(MAIN) LINECOUNT(60)

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      *....*...1.....2.....3.....4.....5.....6.....7.*.....8
      C                                                                 00000010
      C  ...............................................................00000020
      C                                                                 00000030
      C        SUBROUTINE MFGR                                          00000040
      C                                                                 00000050
      C        PURPOSE                                                  00000060
      C           FOR A GIVEN M BY N MATRIX THE FOLLOWING CALCULATIONS  00000070
      C           ARE PERFORMED                                         00000080
      C           (1) DETERMINE RANK AND LINEARLY INDEPENDENT ROWS AND  00000090
      C               COLUMNS (BASIS).                                  00000100
      C           (2) FACTORIZE A SUBMATRIX OF MAXIMAL RANK.            00000110
      C           (3) EXPRESS NON-BASIC ROWS IN TERMS OF BASIC ONES.    00000120
      C           (4) EXPRESS BASIC VARIABLES IN TERMS OF FREE ONES.    00000130
      C  ...........................................................     00000140
      C        USAGE                                                    00000150
      C           CALL MFGR(A,M,N,EPS,IRANK,IROW,ICOL)                  00000160
      C                                                                 00000170
      C        DESCRIPTION OF PARAMETERS                                00000180
      C           A      - GIVEN MATRIX WITH M ROWS AND N COLUMNS.      00000190
      C  ---------------------ON RETURN A CONTAINS THE FIVE SUBMATRICES  00000200
      C                    L, R, H, D, 0.                               00000210
      C           M      - NUMBER OF ROWS OF MATRIX A.                  00000220
      C           N      - NUMBER OF COLUMNS OF MATRIX A.               00000230
      C           EPS    - TESTVALUE FOR ZERO AFFECTED BY ROUNDOFF NOISE.00000240
      C           IRANK  - RESULTANT RANK OF GIVEN MATRIX.              00000250
      C  ---------IROW ---INTEGER VECTOR OF DIMENSION M CONTAINING THE  00000260
      C                    SUBSCRIPTS OF BASIC ROWS IN IROW(1),...,IROW(IRANK)00000270
      C           ICOL   - INTEGER VECTOR OF DIMENSION N CONTAINING THE 00000280
      C                    SUBSCRIPTS OF BASIC COLUMNS IN ICOL(1) UP TO 00000290
      C                    ICOL(IRANK).                                 00000300
      C                                                                 00000310
      C  ---------REMARKS ---------------------------------------------- 00000320
      C           THE LEFT HAND TRIANGULAR FACTOR IS NORMALIZED SUCH THAT00000330
      C           THE DIAGONAL CONTAINS ALL ONES THUS ALLOWING TO STORE ONLY00000340
      C           THE SUBDIAGONAL PART.                                 00000350
      C                                                                 00000360
      C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED            00000370
      C  ---------NONE ------------------------------------------------- 00000380
      C                                                                 00000390
      C        METHOD                                                   00000400
      C  ---------GAUSSIAN ELIMINATION TECHNIQUE IS USED FOR CALCULATION 00000410
      C           OF THE TRIANGULAR FACTORS OF A GIVEN MATRIX.          00000420
      C           COMPLETE PIVOTING IS BUILT IN.                        00000430
      C  ---------IN CASE OF A SINGULAR MATRIX ONLY THE TRIANGULAR FACTORS00000440
      C           OF A SUBMATRIX OF MAXIMAL RANK ARE RETAINED.          00000450
      C           THE REMAINING PARTS OF THE RESULTANT MATRIX GIVE THE  00000460
      C  ---------DEPENDENCIES OF ROWS AND THE SOLUTION OF THE HOMOGENEOUS00000470
      C           MATRIX EQUATION A*X=0.                                00000480
      C                                                                 00000490
      C  ...............................................................00000500
      C                                                                 00000510
ISN     1           SUBROUTINE MFGR(A,M,N,EPS,IRANK,IROW,ICOL)          00000520
      C                                                                 00000530
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                *....*...1.........2.........3.........4.........5.........6.........7.*........8

                C        DIMENSIONED DUMMY VARIABLES                                    00000540
ISN       2          DIMENSION A(1),IROW(1),ICOL(1)                                    00000550
                C                                                                       00000560
                C        TEST OF SPECIFIED DIMENSIONS                                   00000570
ISN       3          IF(M)2,2,1                                                        00000580
ISN       4        1 IF(N)2,2,4                                                        00000590
ISN       5        2 IRANK=-1                                                          00000600
ISN       6        3 RETURN                                                            00000610
                C        RETURN IN CASE OF FORMAL ERRORS                                00000620
                C                                                                       00000630
                C                                                                       00000640
                C        INITIALIZE COLUMN INDEX VECTOR                                 00000650
                C        SEARCH FIRST PIVOT ELEMENT                                     00000660
ISN       7        4 IRANK=0                                                           00000670
ISN       8          PIV=0.                                                            00000680
ISN       9          JJ=0                                                              00000690
ISN      10          DO 6 J=1,N                                                        00000700
ISN      11          ICOL(J)=J                                                         00000710
ISN      12          DO 6 I=1,M                                                        00000720
ISN      13          JJ=JJ+1                                                           00000730
ISN      14          HOLD=A(JJ)                                                        00000740
ISN      15          IF(ABS(PIV)-ABS(HOLD))5,6,6                                       00000750
ISN      16        5 PIV=HOLD                                                          00000760
ISN      17          IR=I                                                              00000770
ISN      18          IC=J                                                              00000780
ISN      19        6 CONTINUE                                                          00000790
                C                                                                       00000800
                C        INITIALIZE ROW INDEX VECTOR                                    00000810
ISN      20          DO 7 I=1,M                                                        00000820
ISN      21        7 IROW(I)=I                                                         00000830
                C                                                                       00000840
                C        SET UP INTERNAL TOLERANCE                                      00000850
ISN      22          TOL=ABS(EPS*PIV)                                                  00000860
                C                                                                       00000870
                C        INITIALIZE ELIMINATION LOOP                                    00000880
ISN      23          NH=N*M                                                            00000890
ISN      24          DO 19 NCOL=M,NH,M                                                 00000900
                C                                                                       00000910
                C        TEST FOR FEASIBILITY OF PIVOT ELEMENT                          00000920
ISN      25        8 IF(ABS(PIV)-TOL)20,20,9                                           00000930
                C                                                                       00000940
                C        UPDATE RANK                                                    00000950
ISN      26        9 IRANK=IRANK+1                                                     00000960
                C                                                                       00000970
                C        INTERCHANGE ROWS IF NECESSARY                                  00000980
ISN      27          JJ=IR-IRANK                                                       00000990
ISN      28          IF(JJ)12,12,10                                                    00001000
ISN      29       10 DO 11 J=IRANK,NH,M                                                00001010
ISN      30          I=J+JJ                                                            00001020
ISN      31          SAVE=A(J)                                                         00001030
ISN      32          A(J)=A(I)                                                         00001040
ISN      33       11 A(I)=SAVE                                                         00001050
                C                                                                       00001060
                C        UPDATE ROW INDEX VECTOR                                        00001070
ISN      34          JJ=IROW(IR)                                                       00001080
ISN      35          IROW(IR)=IROW(IRANK)                                              00001090
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                *....*...1.........2.........3.........4.........5.........6.........7.*.......8
ISN       36          IROW(IRANK)=JJ                                                    00001100
                C                                                                       00001110
                C         INTERCHANGE COLUMNS IF NECESSARY                              00001120
ISN       37       12 JJ=(IC-IRANK)*M                                                   00001130
ISN       38          IF(JJ)15,15,13                                                    00001140
ISN       39       13 KK=NCOL                                                           00001150
ISN       40          DO 14 J=1,M                                                       00001160
ISN       41          I=KK+JJ                                                           00001170
ISN       42          SAVE=A(KK)                                                        00001180
ISN       43          A(KK)=A(I)                                                        00001190
ISN       44          KK=KK-1                                                           00001200
ISN       45       14 A(I)=SAVE                                                         00001210
                C                                                                       00001220
                C         UPDATE COLUMN INDEX VECTOR                                    00001230
ISN       46          JJ=ICOL(IC)                                                       00001240
ISN       47          ICOL(IC)=ICOL(IRANK)                                              00001250
ISN       48          ICOL(IRANK)=JJ                                                    00001260
ISN       49       15 KK=IRANK+1                                                        00001270
ISN       50          MM=IRANK-N                                                        00001280
ISN       51          LL=NCOL+MM                                                        00001290
                C                                                                       00001300
                C         TEST FOR LAST ROW                                             00001310
ISN       52          IF(MM)16,25,25                                                    00001320
                C                                                                       00001330
                C         TRANSFORM CURRENT SUBMATRIX AND SEARCH NEXT PIVOT              00001340
ISN       53       16 JJ=LL                                                             00001350
ISN       54          SAVE=PIV                                                          00001360
ISN       55          PIV=0.                                                            00001370
ISN       56          DO 19 J=KK,M                                                      00001380
ISN       57          JJ=JJ+1                                                           00001390
ISN       58          HOLD=A(JJ)/SAVE                                                   00001400
ISN       59          A(JJ)=HOLD                                                        00001410
ISN       60          L=J-IRANK                                                         00001420
                C                                                                       00001430
                C         TEST FOR LAST COLUMN                                          00001440
ISN       61          IF(IRANK-N)17,19,19                                               00001450
ISN       62       17 II=JJ                                                             00001460
ISN       63          DO 19 I=KK,N                                                      00001470
ISN       64          II=II+M                                                           00001480
ISN       65          MM=II-L                                                           00001490
ISN       66          A(II)=A(II)-HOLD*A(MM)                                            00001500
ISN       67          IF(ABS(A(II))-ABS(PIV))19,19,18                                   00001510
ISN       68       18 PIV=A(II)                                                         00001520
ISN       69          IR=J                                                              00001530
ISN       70          IC=I                                                              00001540
ISN       71       19 CONTINUE                                                          00001550
                C                                                                       00001560
                C         SET UP MATRIX EXPRESSING ROW DEPENDENCIES                     00001570
ISN       72       20 IF(IRANK-1)3,25,21                                                00001580
ISN       73       21 IR=LL                                                             00001590
ISN       74          DO 24 J=2,IRANK                                                   00001600
ISN       75          II=J-1                                                            00001610
ISN       76          IR=IR-M                                                           00001620
ISN       77          JJ=LL                                                             00001630
ISN       78          DO 23 I=KK,M                                                      00001640
ISN       79          HOLD=0.                                                           00001650
```

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                 *....*...1.....2.....3.....4.....5.....6.....7.*.....8
                                                                                00001660
ISN       80          JJ=JJ+1                                                   00001670
ISN       81          MM=JJ                                                     00001680
ISN       82          IC=IR                                                     00001690
ISN       83          DO 22 L=1,II                                              00001700
ISN       84          HOLD=HOLD+A(MM)*A(IC)                                     00001710
ISN       85          IC=IC-1                                                   00001720
ISN       86       22 MM=MM-M                                                   00001730
ISN       87       23 A(MM)=A(MM)-HOLD                                          00001740
ISN       88       24 CONTINUE                                                  00001750
                C                                                              00001760
                C     TEST FOR COLUMN REGULARITY                               00001770
ISN       89       25 IF(N-IRANK)3,3,26                                         00001780
                C                                                              00001790
                C        SET UP MATRIX EXPRESSING BASIC VARIABLES IN TERMS OF FREE 00001800
                C      PARAMETERS (HOMOGENEOUS SOLUTION).                      00001810
ISN       90       26 IR=LL                                                     00001820
ISN       91          KK=LL+M                                                   00001830
ISN       92          DO 30 J=1,IRANK                                           00001840
ISN       93          DO 29 I=KK,NM,M                                           00001850
ISN       94          JJ=IR                                                     00001860
ISN       95          LL=I                                                      00001870
ISN       96          HOLD=0.                                                   00001880
ISN       97          II=J                                                      00001890
ISN       98       27 II=II-1                                                   00001900
ISN       99          IF(II)29,29,28                                            00001910
ISN      100       28 HOLD=HOLD-A(JJ)*A(LL)                                     00001920
ISN      101          JJ=JJ-M                                                   00001930
ISN      102          LL=LL-1                                                   00001940
ISN      103          GOTO 27                                                   00001950
ISN      104       29 A(LL)=(HOLD-A(LL))/A(JJ)                                  00001960
ISN      105       30 IR=IR-1                                                   00001970
ISN      106          RETURN                                                    00001980
ISN      107          END

*STATISTICS*  SOURCE STATEMENTS = 107,  PROGRAM SIZE = 3062 BYTES,  PROGRAM NAME = MFGR     PAGE:  74.

*STATISTICS*     NO DIAGNOSTICS GENERATED.

******* END OF COMPILATION 43 *******
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POOR

QUALITY

ORIGINAL